INSTRUCTION MANUAL

RECTANGULAR COORDINATE
PATTERN RECORDER

SERIES APR 20

SERIAL NO. 3 0 1

MP MASTER

MA29836

SCIENTIFIC-ATLANTA, INC.

P. O. BOX 13654, ATLANTA 24, GEORGIA (3845 Pleasantdale Road — at NE Expressway)

Telephone 404-938-2930 • TWX: 404-938-1322 • WUX • Cable SCIATLA

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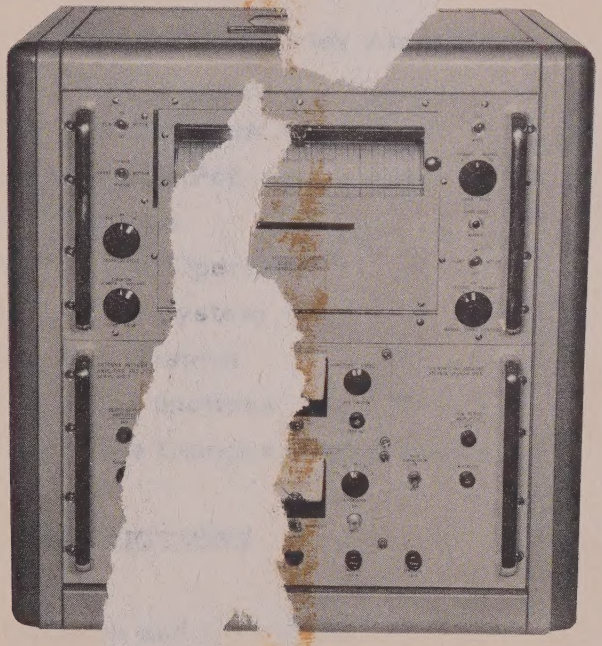

MODEL APR 23

Fourth Edition
March 1962

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# I. GENERAL DESCRIPTION

## 1.1 Introduction

Scientific-Atlanta, Inc., Series APR 20 Rectangular Coordinate Pattern Recorders are designed to permit rapid and accurate recording of either of three functions of the amplitude of a received signal plotted versus an angular function of the reception or transmission device. These recorders are ideally suited for making permanent radiation pattern recordings of reception and transmission devices sensitive to media such as radio frequencies, heat, light, sound, etc.

When fed from a square-law detector or transducer, the recording may be presented as a function of the received power, the received voltage, or the logarithm of the received power or voltage. When fed from a linear detector or transducer, the recording may be presented as a function of the received voltage or as the logarithm of the received power or voltage. To accomplish the preceding presentations, the recorders may be furnished with one or a choice of two or more of the following pen functions: linear pen motion versus recorder input voltage; square-root pen motion versus recorder input voltage; logarithmic pen motion versus recorder input voltage.

The recorder will respond to an 80 db dynamic range of input signal providing an 80 db logarithmic scale when fed from a linear detector and a 40 db logarithmic scale when fed from a square-law detector.

To permit operation from a detector receiving an audio-modulated carrier, the recorder is furnished with a narrow-band crystal-bolometer amplifier. When using this amplifier, the recorder and the detector comprise a sensitive video detection receiving system. The detector may be coupled directly to an antenna under test or to the output of a receiving system for improvement of the over-all sensitivity.

To permit operation from a dc input signal, the crystal-bolometer amplifier is replaced by a dc-chopper preamplifier. This permits direct recording from the output of a transducer or a detector receiving an unmodulated signal.

## 1.2 Specifications

### 1.2.1 Chart System:

| | |
|---|---|
| Chart Cycle (length) | 20 inches |
| Chart Expansion | 1:1, 6:1, 36:1 |
| Chart Speed (maximum) | 12 inches-per-second |
| Chart Position Error | 0.02 inch static, 0.06 inch at 4 inches-per-second |
| Chart Cycle Advance | automatic |
| Chart Operation (manual) | forward-reverse at variable speed |
| Chart Zero | manual |

### 1.2.2 Pen System:

| | |
|---|---|
| Pen Writing Speed | 40 inches-per-second |
| Pen Lift | manual or foot-switch |
| Pen Responses Available | |
| Model APR 21 | linear |
| Model APR 22 | logarithmic |
| Model APR 23 | linear-logarithmic |
| Model APR 24 | linear-square root |
| Model APR 25 | linear-logarithmic-square root |
| Pen Response Accuracy | |
| Linear | ±0.5% of full scale |
| Square-root | ±0.5% of full scale, first 20 db<br>±1.0% of full scale, next 20 db |
| Logarithmic | ±0.25 db |
| Pen Motor Control (On-Off) | manual or remote |
| Noise Compression (Noise Improvement) | 10 db referred to recorder input<br>5 db referred to square-law input |
| Function Potentiometers | plug-in |

### 1.2.3 Crystal-Bolometer Amplifier (Models CBA 21, CBA 21R, CBA 22):

| | |
|---|---|
| Input Noise (Referred to 600 ohm Source Impedance) | 0.025 microvolt |
| Center Frequency (standard) | 1000 cps |

| | |
|---|---|
| Range of Center Frequencies Available | between 500 cps and 2500 cps |
| Bandwidth (3 db) | center frequency ±2.0% |
| Over-all Gain | 100 db |
| Full Scale Sensitivity: | |
| Linear | 1 microvolt |
| Square-root | 10 microvolts |
| Logarithmic | 100 microvolts |
| Attenuation*: | |
| Fixed | three 10 db steps |
| Variable | 10 db |

1.2.4 DC-Chopper Preamplifier (Model DCA 21):

| | |
|---|---|
| Over-all Gain (dc to rms ac) | 20 db |
| Full Scale Sensitivity: | |
| Linear | 10 millivolts |
| Square-root | 100 millivolts |
| Logarithmic | 1 volt |
| Attenuation**: | |
| Fixed | three 20 db steps |
| Variable | 20 db |
| Attenuator Accuracy (Fixed Steps) | ±1% of full scale |
| Chopper Frequency | 400 cps |

1.2.5 Pen Function Amplifiers:

| | |
|---|---|
| Model PFA 21 | linear |
| Model PFA 22 | logarithmic |
| Model PFA 23 | linear-logarithmic |
| Model PFA 24 | linear-square root |
| Model PFA 25 | linear-logarithmic-square root |
| Signal Level Meter Calibration (All Models) | 0-20 db<br>0-40 db |

*Attenuation referred to square-law recorder input.

**Attenuation referred to linear recorder input.

1.2.6 Plug-in Potentiometers:

| | |
|---|---|
| P-1 | linear |
| P-2 | linear-square root |
| P-3 | logarithmic (40 db) |
| P-3-20 | logarithmic (20 db) |
| P-4* | logarithmic (60 db) |

1.2.7 General:

Power Requirements

| | |
|---|---|
| Voltage | 115 |
| Frequency | 50-60 cps |
| Watts | 300 |
| Weight | 155 pounds |

## 1.3 Principles of Operation

The Series APR 20 Rectangular Pattern Recorder consists of two high speed servo systems each employing tachometer feedback. One servo positions a recording chart in response to the angular position of a remote synchro transmitter; the other positions a recording pen in response to a function of the signal applied to the input of the recorder preamplifier.

### 1.3.1 Chart System:

Figure 1 is a block diagram of the Series APR 20 Rectangular Coordinate Pattern Recorder. Chart position data is normally obtained from either of two synchro transmitters; one geared 1 to 1 with respect to the antenna turntable, the other geared 36 to 1 with respect to the antenna turntable. The pattern recorder incorporates two synchro transformers; one geared 1 to 1 with respect to the 20-inch chart cycle, the other geared 1 to 6 with respect to the 20-inch chart cycle.

A DEGREES/CYCLE switch permits the selection of any one of three drive ratios between the antenna turntable and the 20-inch chart cycle: the 360-degree position connects the 1 to 1 synchro transmitter to the 1 to 1 synchro transformer located in the pattern recorder pro-

*Used in combination with Series 402 Wide Range Receiving System.

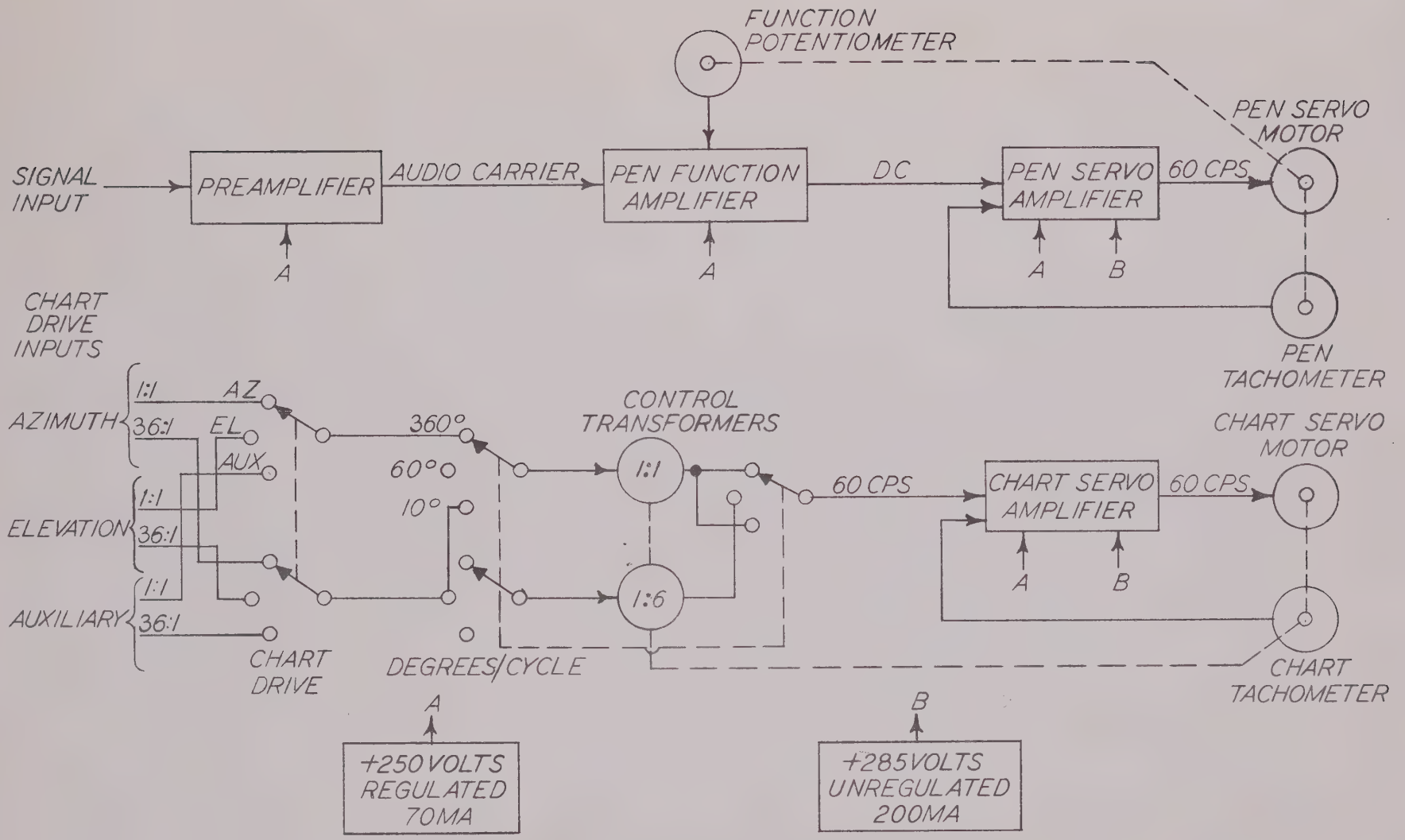


Figure 1. Block Diagram of Series APR 20 Rectangular Coordinate Pattern Recorder.

viding one chart cycle for 360 degrees of turntable rotation. The 60-degree position connects the 36 to 1 synchro transmitter to the 1 to 6 synchro transformer located in the pattern recorder providing one chart cycle for 60 degrees of turntable rotation; the 10-degree position connects the 36 to 1 synchro transmitter to the 1 to 1 synchro transformer located in the pattern recorder providing one chart cycle for 10 degrees of turntable rotation. A CHART MOTION switch (not shown by Figure 1) provides selection of the direction of chart rotation during normal operation.

A CHART DRIVE switch provides selection of any one of three pairs of synchro inputs to drive the chart. These inputs are labeled AZIMUTH, ELEVATION, and AUXILIARY. This permits rapid switching of the chart system between axes of an antenna positioner or between antenna positioners.

The chart servo amplifier is a 60 cps amplifier which accepts an error signal from the appropriate control transformer and drives the chart servo motor. The chart servo motor includes an integral tachometer providing damping control.

An automatic chart cycle advance circuit permits advance of the chart in the forward direction by exactly one chart cycle (20 inches). This automatic advance is accomplished by pressing the CHART CYCLE ADVANCE button.

A MANUAL CHART CONTROL switch permits the chart to be manually operated in either the forward or reverse direction.

A CHART ZERO control permits alignment of the chart roll with any desired reference on the antenna turntable.

1.3.2 Pen System:

The control signal for the pen system is applied to the input of a preamplifier which furnishes an audio carrier to the pen function amplifier. The preamplifier may be either a crystal-bolometer amplifier (See Crystal-Bolometer Amplifier Instruction Manual) or a dc-chopper preamplifier (See DC-Chopper Preamplifier Instruction Manual). The frequency of the audio carrier fed to the pen function amplifier depends on the type of preamplifier and its center frequency. This frequency will be in the frequency range between 400 cps and 2500 cps.

The pen function amplifier (See Pen Function Amplifier Instruction Manual) provides additional amplification of the audio carrier and furnishes a dc error voltage to the pen servo amplifier. In addition, the pen function amplifier includes the circuits which together with the proper plug-in potentiometer determine the pen function. Five plug-in models of the pen function amplifier are available permitting a pattern recorder to have a single pen function which is either linear or logarithmic, a choice of two pen functions (linear-square root or linear-logarithmic) or a choice of three pen functions (linear-logarithmic-square root).

The dc output of the pen function amplifier is fed to the pen servo amplifier. This amplifier converts the dc input into a 60-cycle signal and delivers a 60-cycle output to the pen servo motor. The pen servo motor has an integral tachometer which is fed into the pen servo amplifier to provide pen damping. The recording pen and the appropriate function potentiometer or potentiometers are driven by the pen servo motor.

1.3.3 Pen Functions:

Figure 2A shows a block diagram of the basic circuit arrangement which provides the linear pen function. It is desired to provide a recorder pen displacement (P) which is directly proportional to the amplitude of the input signal $E_s$. The quantities shown by Figure 2A are as follow:

| | |
|---|---|
| $E_s$ | input signal |
| A | amplifier gain |
| $E_d$ | amplifier output |
| $-E_b$ | reference voltage |
| $-E_r$ | potentiometer arm potential |
| e | error signal |
| P | recording pen displacement |

The equations which describe the circuit operation are as follows:

(1) $$E_d = AE_s$$

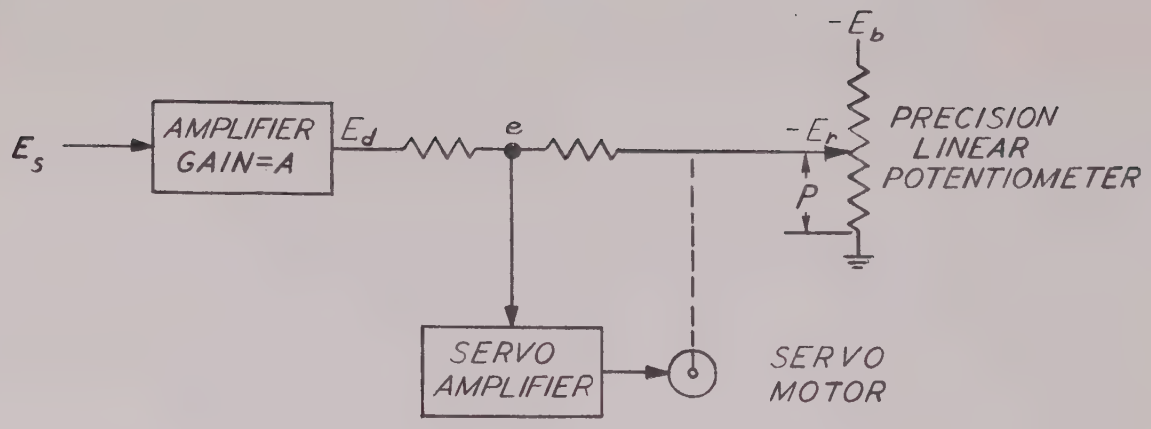


Figure 2A. Simplified Linear Pen Function Circuit.

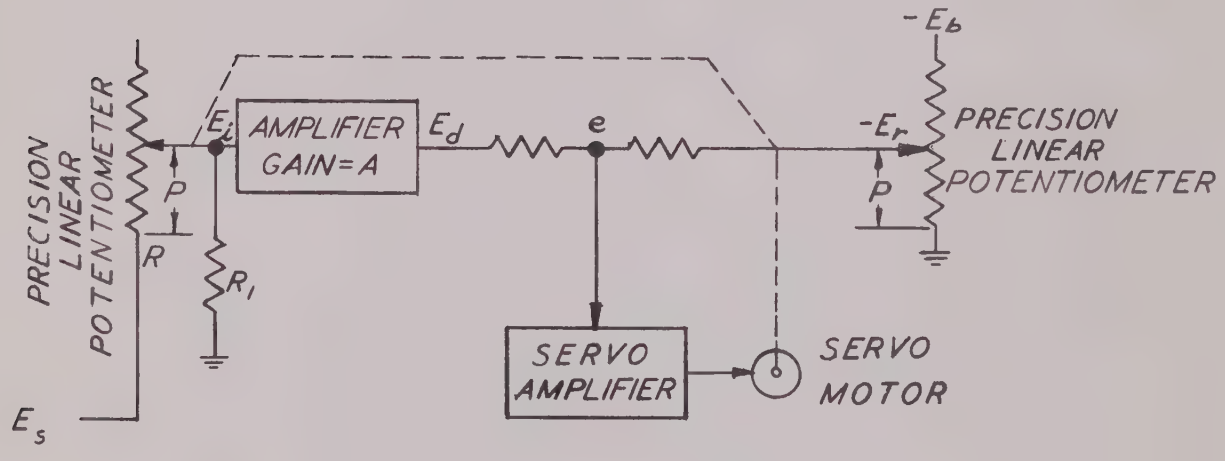


Figure 2B Simplified Square-Root Pen Function Circuit.

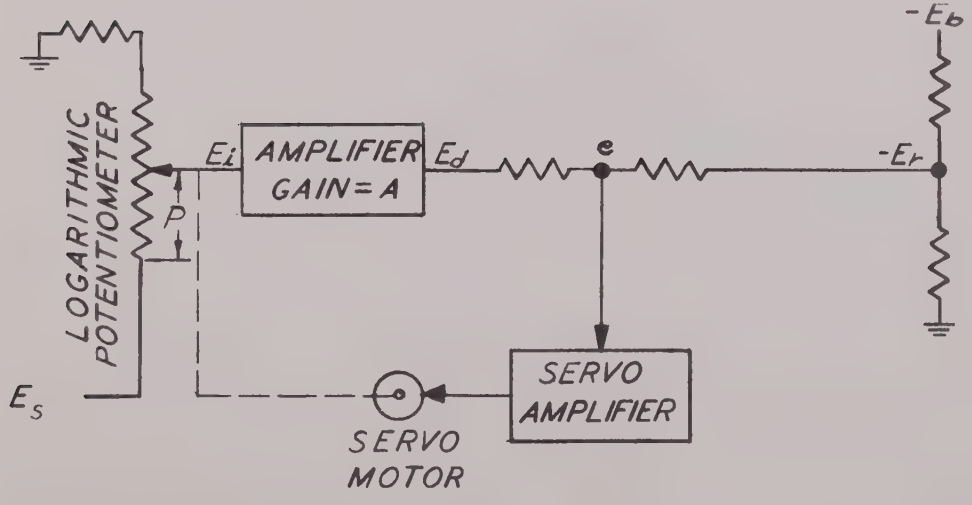


Figure 2C. Simplified Logarithmic Pen Function Circuit.

(2) $$E_r = PE_b$$

With the high gain servo loop continually adjusting $-E_r$ to balance $E_d$ maintaining the error signal (e) at minimum or zero, then:

(3) $$E_r = E_d$$

Substituting $PE_b$ for $E_r$ and $AE_s$ for $E_d$ gives:

(4) $$PE_b = AE_s$$

Since A and $E_b$ are constants:

(5) $$\underline{P = KE_s}$$

Figure 2B shows a block diagram of the basic circuit arrangement which provides the square-root pen function. In this case, it is desired to provide a recorder pen displacement (P) which is directly proportional to the square-root of the amplitude of the input signal ( $E_s$). The quantities shown by Figure 2B are as follow:

| | |
|---|---|
| $E_s$ | input signal |
| $E_i$ | amplifier input |
| R | linear potentiometer resistance |
| $R_l$ | load resistance |
| A | amplifier gain |
| $E_d$ | amplifier output |
| $-E_b$ | reference voltage |
| $-E_r$ | potentiometer arm potential |
| e | error signal |
| P | recording pen displacement |

The equations which describe the circuit operation are as follow:

(1) $$E_i = \frac{E_s R_1}{R_1 + PR}$$

If $R_1 << PR$, which is accomplished over the desired range of P by making R large and $R_1$ small then:

(2) $$E_i = \frac{E_s R_1}{PR}$$

(3) $$E_d = AE_i$$

(4) $$E_d = \frac{AE_s R_1}{PR}$$

(5) $$E_r = PE_b$$

With the high gain servo loop continually adjusting $-E_r$ to cancel $E_d$ maintaining the error signal (e) at minimum or zero then:

(6) $$E_r = E_d$$

Since the two linear potentiometers are mechanically ganged the pen displacement is common to both. Substituting $PE_b$ for $E_r$ and $\frac{AE_s R_1}{PR}$ for $E_d$ gives.

(7) $$PE_b = \frac{AE_s R_1}{PR}$$

(8) $$P^2 = \frac{AE_sR_1}{RE_b}$$

Since $\frac{AR_1}{RE_b}$ is constant:

(9) $$\underline{P = K\sqrt{E_s}}$$

Figure 2C shows a block diagram of the basic circuit arrangement which provides the logarithmic pen function. In this case, it is desired to provide a recorder pen displacement (P) which is directly proportional to the logarithm of the amplitude of the input signal ($E_s$). The quantities shown by Figure 2C are as follow:

| | |
|---|---|
| $E_s$ | input signal |
| $E_i$ | amplifier input |
| A | amplifier gain |
| $E_d$ | amplifier output |
| $-E_r$ | reference voltage |
| e | error signal |
| P | recording pen displacement |

The equations which describe the circuit operation are as follow:

(1) $$E_i = \frac{E_s}{\log^{-1} P}$$

(2) $$E_d = \frac{AE_s}{\log^{-1} P}$$

With the high gain servo loop continually adjusting $E_d$ to cancel $-E_r$ maintaining the error signal (e) at minimum or zero, then:

$$E_r = E_d \tag{3}$$

Substituting $\frac{AE_s}{\log^{-1} P}$ for $E_d$ gives.

$$E_r = \frac{AE_s}{\log^{-1} P} \tag{4}$$

$$P = \log \frac{A}{E_r} + \log E_s \tag{5}$$

Since $\frac{A}{E_r}$ is constant

$$\underline{P = \log E_s + K} \tag{6}$$

1.3.4 Noise Compression Circuit.

The noise compression circuit is located in the 60 cps pen servo amplifier and provides a reduction of the recording pen noise response equivalent to 10 db of signal level referred to the recorder input. (Figure 3 illustrates the noise improvement to be expected when the noise compression circuit is used during recording.)

A NOISE COMPRESSION switch permits the noise compression circuit to be either inserted or removed from the pen servo amplifier. When in the OFF position of the NOISE COMPRESSION switch, the noise compression circuit is removed from the pen servo amplifier. When in the ON position of the NOISE COMPRESSION switch, the noise compression circuit is inserted in the pen servo amplifier as shown by Figure 4.

The noise compression circuit performs three basic functions

a. Circuit A consisting of R6, CR5, and CR6 limits the level of the error signal fed to the 60 cps output amplifier to a

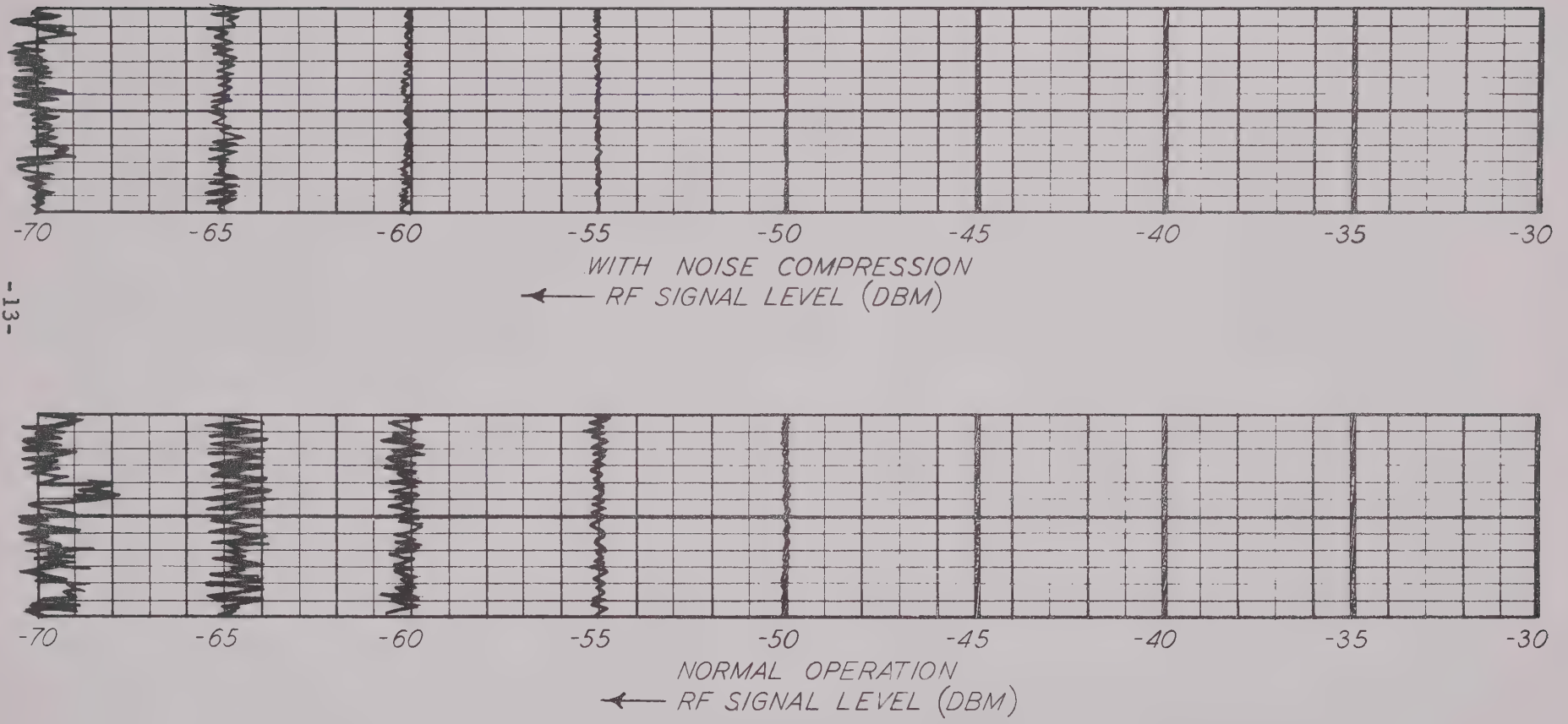


Figure 3. Typical Recorder Noise versus R F Signal Level With and Without Noise Compression. (Operation at "X" Band using 1N23C Crystal)

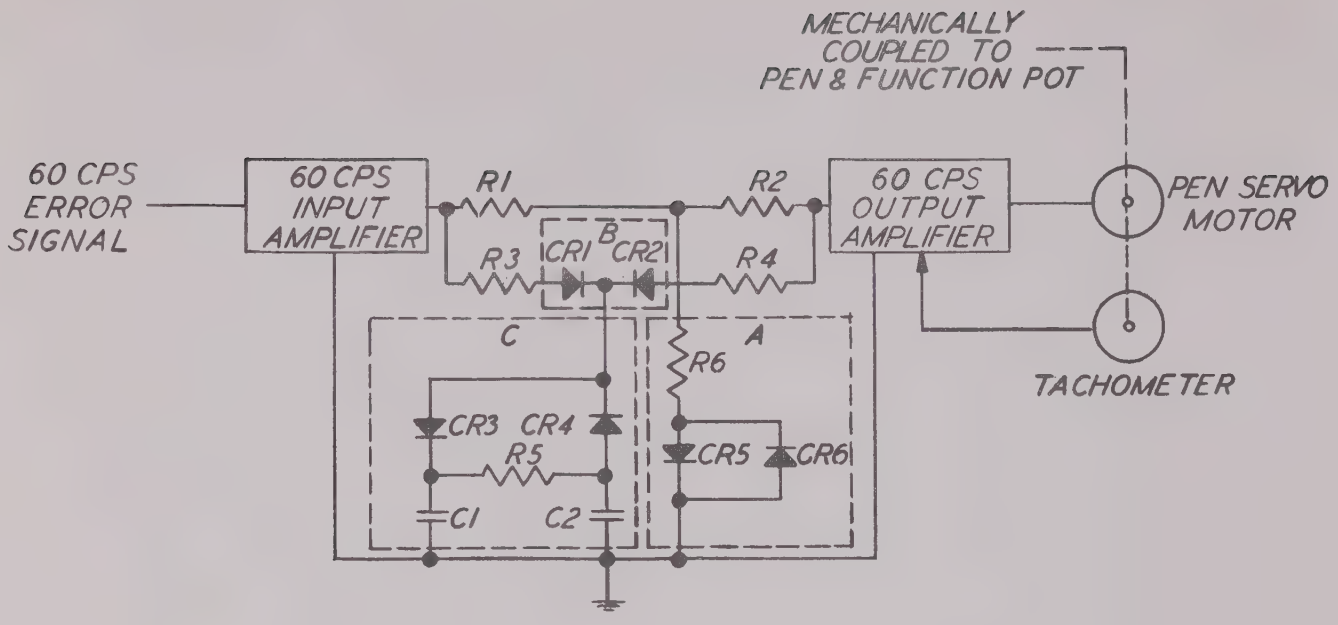


Figure 4. Simplified Noise Compression Circuit.

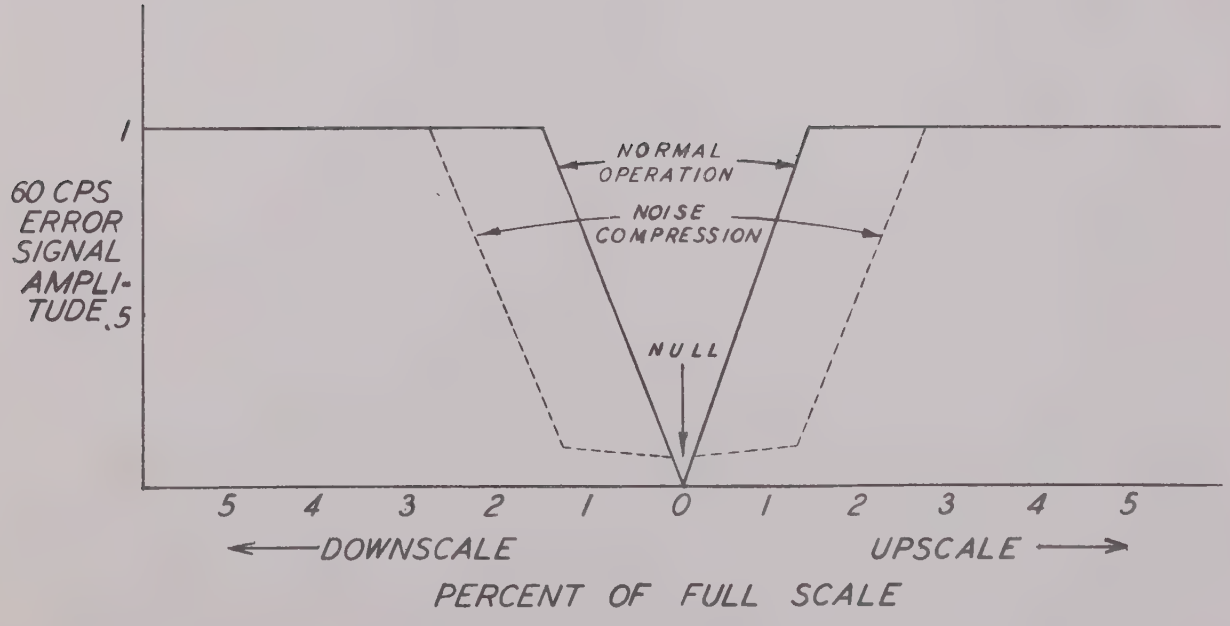


Figure 5. Error Signal versus Pen Displacement from Null for Normal and Noise Compression Operation.

value which provides a maximum pen slewing speed of approximately 2 to 3 inches-per-second. Since CR5 and CR6 are silicon diodes requiring approximately 0.5 volts of applied signal before conduction, the recording pen response is unaffected when the recording pen is within a region of approximately ±0.02 inch of the null.

b. Circuit B consisting of CR 1 and CR 2 restores full error voltage when displacement of the recording pen from the null exceeds a predetermined value. Full error voltage is coupled to the 60 cps output amplifier upon conduction of CR 1 and CR 2. The voltage required to render CR 1 and CR 2 conductive corresponds to the applied error voltage present when the recording pen is displaced from null by 0.125 inch. This corresponds to 1.25 per cent of the full linear scale or approximately ±0.5 db of the logarithmic scale.

c. Circuit C consisting of CR3, CR4, R5, C1, and C2 discriminates between random noise and a constant error signal. The diodes are germanium diodes and conduct upon application of potential. Upon conduction of CR3 and CR4, Circuit B is loaded and the response of the servo amplifier is limited by Circuit A. Circuit C is disabled by a bias voltage built up on C1 and C2 when a constant error voltage is applied. The time constant provided by R5, C1, and C2 is sufficiently short to allow Circuit C to disable Circuit B only when random error signals of short duration are present.

Figure 5 shows the over-all response of the pen servo amplifier for normal operation and when using the noise compression circuit. The solid curve represents the relative amplitude of the error signal plotted versus pen displacement from a null during normal operation. In this case, a maximum pen slewing speed of 40 inches-per-second is attained. The dashed curve shows the deviation from the normal amplifier response when using the noise compression circuit. At a region within ±0.2 per cent of the null, the amplifier response is unaffected. In the region between

±0.2 per cent of the null and ±1.25 per cent of the null, the amplifier response is limited. Outside the region of ±1.25 per cent of the null, the full error signal is applied for non-random signals.

The over-all effect of the noise compression circuit is to provide a pen response similar to that obtained with a preamplifier having a 4 cps bandwidth without incurring the modulation frequency stability requirement and slow response limitation of the narrow-band amplifier. The noise compression circuit permits pattern recording at normal recording speeds with a maximum dynamic system error of ±1.25 per cent of the full linear scale or ±0.5 db of the logarithmic scale. The static or slow speed (pen speeds less than 2 inches-per-second) error is not increased over that specified for normal operation. (See Figure 6.) At maximum pen speeds between 2 inches-per-second and 20 inches-per-second the error due to the noise compression circuit is less than the maximum (±1.25 per cent of full scale) and proportional to the pen speed. As can be seen by the lower curve of Figure 6, the apparent effect of the amplitude lag is to displace the over-all pattern slightly on the axis of the chart.

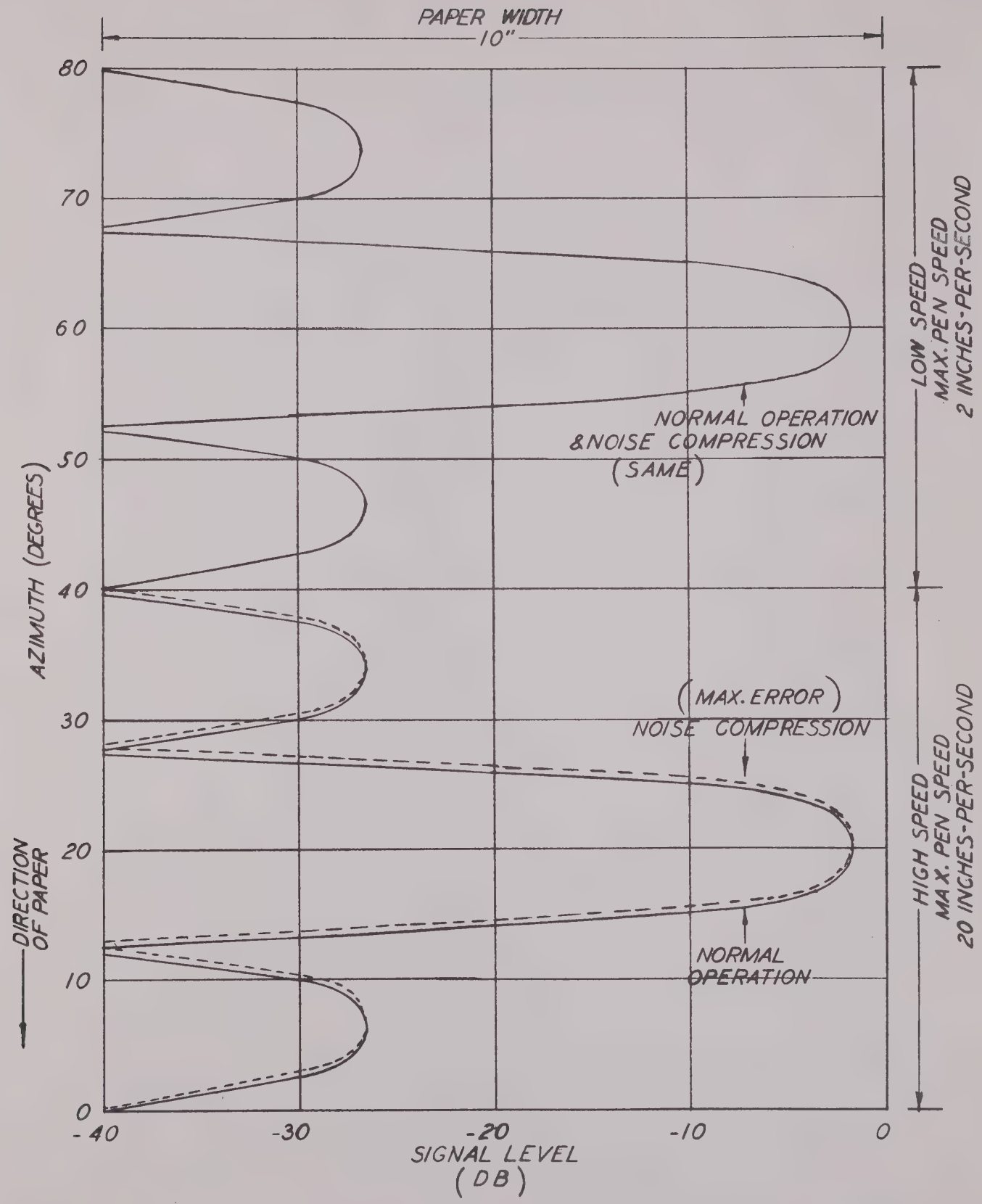


Figure 6. Error Due to Noise Compression Circuit at High and Low Pen Speeds.

# II. OPERATING INSTRUCTIONS

## 2.1 Installation and Operation

The Series APR 20 Rectangular Pattern Recorder operates from a 115 v, 50-60 cps line and requires approximately 300 watts of input power. A visual inspection of all cables and tubes to assure proper placement should be made after uncrating. A preamplifier and a pen function amplifier will be plugged into the lower and upper compartments of the amplifier and power supply chassis on portable models. These units may be separately rack-mounted and remoted from the recorder when the recorder is console mounted. In this case, the plug-in compartments of the recorder will have blank covers.

A Scientific-Atlanta Series PX 1 Synchro Transmitter Unit or its equivalent should be used to furnish synchro data for the chart system (See Figure 7). This unit should be mechanically coupled to the required axis of the antenna positioner. The pattern recorder has three input connectors and a CHART DRIVE switch to permit front panel selection of any one of three synchro transmitter units, each coupled to a separate positioner axis. Connection from each recorder chart synchro input to a Series PX 1 Synchro Transmitter Unit requires an 8-conductor cable fitted with Amphenol AN3106A-20-7S and AN 3106A-20-7P cable connectors. Cable conductor size should be sufficient to carry 0.5 amperes.

The output from a crystal or bolometer detector is normally connected to the INPUT of the crystal-bolometer amplifier. If a bolometer is used, the BOLOMETER CURRENT control should be turned fully counter-clockwise before connecting the bolometer. The CRYSTAL-CURRENT-BOLOMETER switch should be placed in the CURRENT position while adjusting the bolometer current. After adjustment, this switch should be thrown to the BOLOMETER position.

For operation from a crystal detector, the CRYSTAL-CURRENT-BOLOMETER switch must be in the CRYSTAL position.

In recorders furnished with a dc-chopper preamplifier in place of the crystal-bolometer amplifier, a dc input signal is fed to the INPUT connector. For complete details of preamplifier operation, see the instruc-

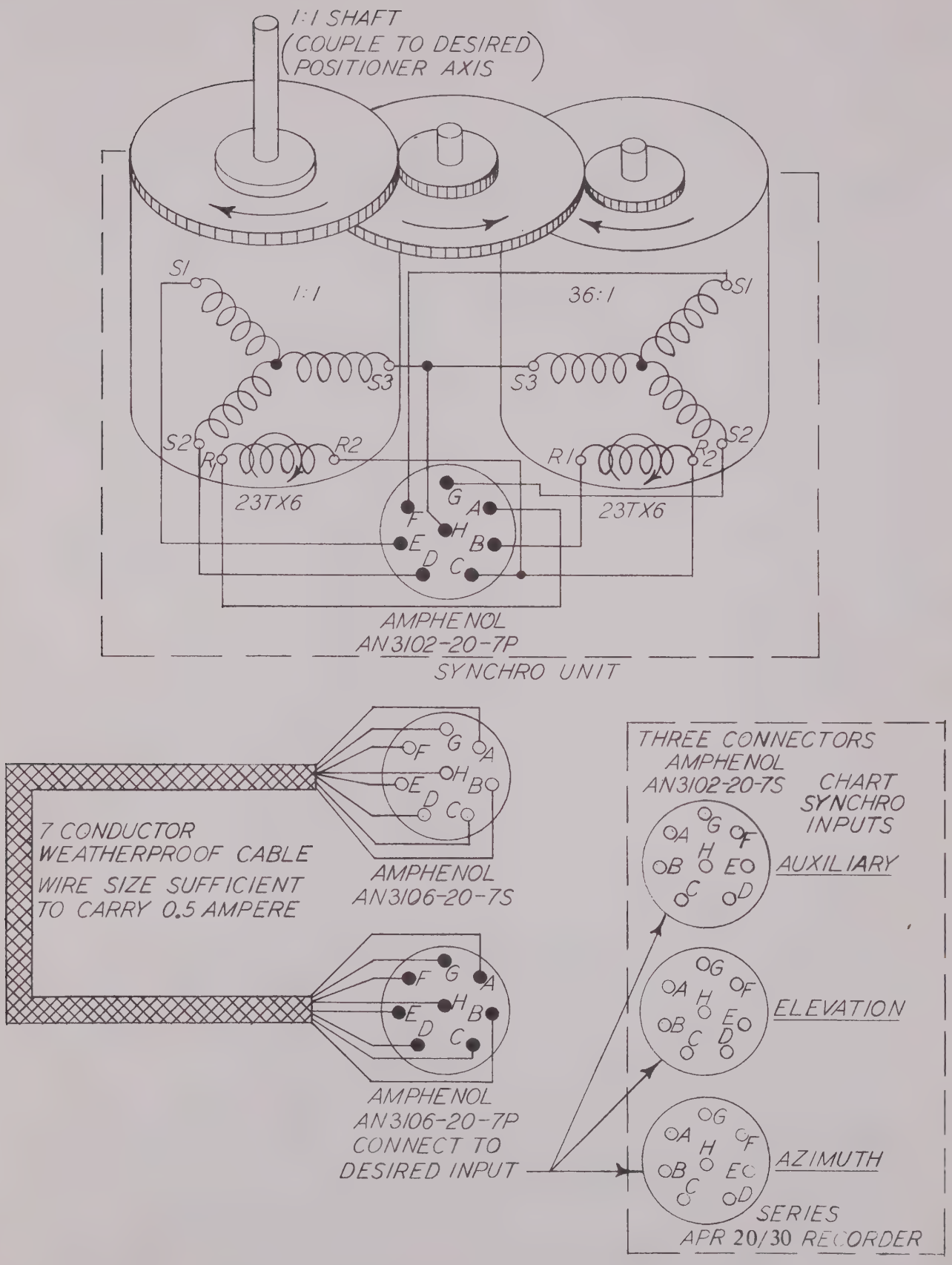


Figure 7. Chart System Connections to Series PX 1 Synchro Unit.

tion manual furnished with the particular plug-in unit.

The recorder pen functions available are determined by the particular pen function amplifier and plug-in potentiometers furnished. The proper plug-in potentiometer and pen function amplifier combination must be employed to obtain a particular pen function. For specific information concerning the proper plug-in potentiometer for a particular pen function, see the pen function amplifier instruction manual provided.

## 2.2 Chart System Controls

The pattern recorder head has seven front-panel controls which determine the operation of the chart system. The name and function of each control follows:

a. CHART MOTOR (ON-OFF)

Purpose: This switch allows the chart drive motor to be turned off when not in use.

b. CHART ZERO (FORWARD-REVERSE)

Purpose: Depressing this knob engages a bevel gear and releases a spring-loaded clutch. Turning the knob while it is depressed enables the chart paper to be oriented to a desired position with respect to the antenna turntable.

c. MANUAL CHART CONTROL (FORWARD-OFF-REVERSE).

Purpose: This rotary switch permits manual drive of the chart roll in either the forward or reverse direction to allow rolling or unrolling the chart. The speed of chart rotation in the FORWARD or REVERSE position may be adjusted by the Manual Speed potentiometer located behind the DEGREES/CYCLE switch. This control also determines the chart speed during the automatic chart cycle advance period.

d. CHART CYCLE ADVANCE

Purpose: Depressing the CHART CYCLE ADVANCE button provides an automatic advance of the chart roll by

exactly one cycle (20 inches). This permits rapid advance of the chart while maintaining the chart reference angle for a new recording.

e. CHART DRIVE (AZIMUTH-ELEVATION-AUXILIARY)
Purpose: This selector switch permits the rapid selection of any one pair of three predetermined pairs of synchro inputs for chart synchronization.

f. DEGREES/CYCLE (360-60-10)
Purpose: This switch permits the selection of one of three chart scales. These are 360 degrees per chart cycle, 60 degrees per chart cycle, and 10 degrees per chart cycle. All chart scales are available only when both the 1 to 1 and the 36 to 1 synchro transmitters are used.

g. CHART MOTION (FORWARD-REVERSE)
Purpose: This switch permits the direction of the chart roll drive to be reversed with respect to the direction of rotation of the synchro transmitters and antenna turntable.

## 2.3 Pen System Controls

The performance of the pen system is determined by controls located on the front panel of the pattern recorder head, controls located on the front panel of the plug-in preamplifier and pen function amplifier, and remote controls which may be connected at the rear of the pattern recorder head. For a description of the controls located on the crystal-bolometer amplifier, the dc-chopper preamplifier, or the pen function amplifier, refer to the separate instruction manual furnished with a particular unit. A description of the controls located on the front panel and the remote controls which may be connected at the rear of the recorder head follows:

a. PEN (LIFT-WRITE)
Purpose: This switch permits the pen to be lifted from the chart writing surface when ink recording is not required.

The pen should be lifted when positioning or replacing the chart and when it is necessary to refill or replace the pen.

b. PEN MOTOR (ON-OFF)

Purpose: This switch permits the pen drive motor to be turned off when recording is not desired. The pen motor should be turned off when cable connections affecting the pen position are being made and when recording is not desired. A minimum of function potentiometer wear can be achieved by not allowing the pen to idly follow large random noise signals for long periods of time.

c. PEN LIFT - Remote Control

Purpose: A foot operated switch may be attached to the rear of the pattern recorder head to provide foot operation of the pen lift circuit when the PEN LIFT switch is in the LIFT position. Use of the foot switch provides a convenient means of beginning and terminating the inking of a pattern.

d. PEN MOTOR (ON-OFF) - Remote Control

A connection is provided at the rear of the recorder head to permit remote ON-OFF control of the pen motor. For remote operation, the PEN MOTOR switch must be in the OFF position. This feature permits the pen motor to be remotely controlled when the recorder is operated in conjunction with an analogue computer.

## 2.4 Loading Chart Paper

When installing a new chart roll in the pattern recorder, orient the paper roll with the paper rolling off the top of the roll toward the operator. Open the doors of the recorder head and seat the hole at the right-hand end of the paper roll core over the hub of the disc (A, Figure 8) located at the right of the paper roll compartment. Push the chart roll and disc to the right and align the hole at the left-hand end of the paper roll core with the hub at the left of the paper roll compartment. Relieve the pressure to the right and rotate the left-hand disc until the key (B, Figure 8) is aligned with the

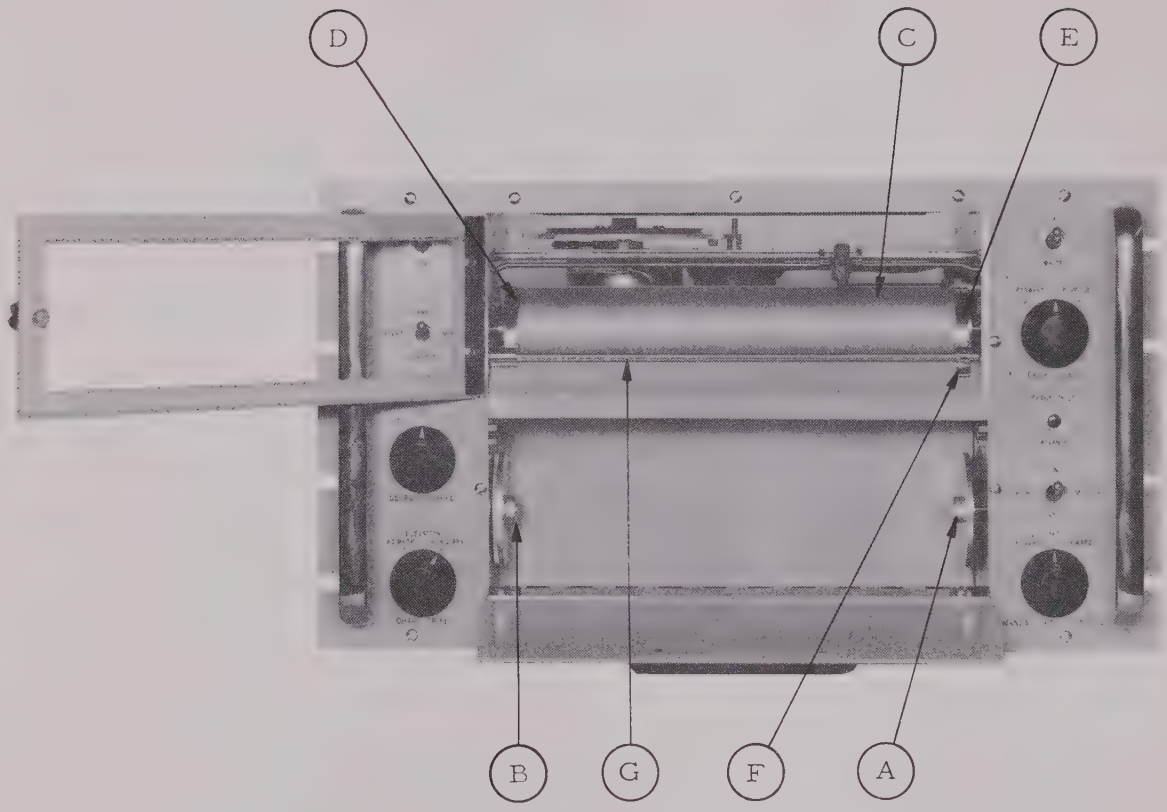


Figure 8. Front View of Rectangular Pattern Recorder Head.

slot in the left-hand end of the paper roll core. Pull the roll to the left until it is firmly seated against the left-hand disc.

Tear off both corners of the end of the chart to form a point at the center and feed the paper under the chart drive cylinder (C, Figure 8) until the point on the chart can be pulled over the top of the cylinder. Pull the paper through and feed the sides under the hold-down clips (D and E, Figure 8). Continue to pull the paper slowly until the holes at each end of the paper are firmly seated over the sprockets. If necessary, lift the hold-down clips with the finger lift tab (F, Figure 8) to aid in seating the paper symmetrically over the sprocket.

## 2.5 Removal and Installation of Plug-in Potentiometer

To allow removal of the plug-in potentiometer, disconnect the cable connector from the bottom of the potentiometer housing. Grasp the potentiometer and rotate approximately 45 degrees counterclockwise, pull downward, and remove potentiometer.

To install a plug-in potentiometer, hold the potentiometer with the cable connector down. From the front of the recorder observe the two holes in the side of the potentiometer casting and orient the potentiometer with one hole facing to the rear of the recorder and one hole facing to the left of the recorder (A, Figure 9). Orient the potentiometer arm (B, Figure 9) with the hole in the potentiometer casting faceing to the left. Turn the slotted arm (C, Figure 9) fixed to the shaft below the pen drive panel (D, Figure 9) to face the left of the recorder. While maintaining the described orientation, insert the potentiometer into position and guide the potentiometer pin into the slot provided. This can be seen through the cut-out (E, Figure 9) in the left end plate of the recorder. Press the potentiometer upward and rotate clockwise until the potentiometer is locked firmly in position. Attach the connector to the bottom of the potentiometer. The plug-in potentiometer is now ready for operation.

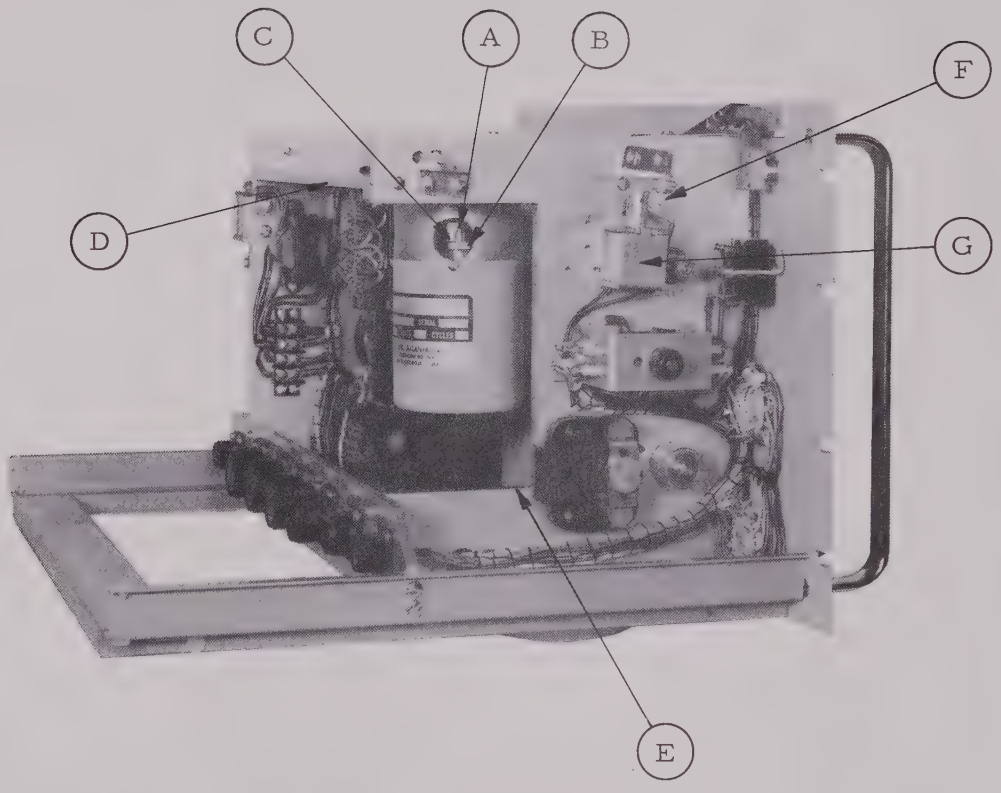


Figure 9. Left Side View of Rectangular Pattern Recorder Head.

## 2.6 Operational Notes

a. Connection of the ground wire provided in the power cord to a zero potential ground is recommended unless another ground path is provided as may be the case when the recorder is housed in a console.

b. Avoid dual grounds causing ground loop currents wherever possible.

c. Always place the CRYSTAL-CURRENT-BOLOMETER switch in the CRYSTAL position when operating from a crystal detector and in the BOLOMETER position when operating from a bolometer detector. Be sure the BOLOMETER CURRENT control is fully counterclockwise before inserting a new bolometer.

d. The step attenuator located on the crystal-bolometer amplifier front panel may be used to obtain accurate antenna patterns exceeding a 40 db dynamic range. This is particularly useful in examining side lobes and nulls of a pattern.

e. Use the PEN LIFT switch to prevent inking when recording is not required.

f. The average life of the balance potentiometer is 2-million cycles. When not actually recording, the PEN MOTOR should be turned OFF, especially if the noise level is high.

g. Use the signal level meter as a level indicator when recording is not desired. This will greatly increase potentiometer life.

h. In normal operation, pens will need cleaning every two or three days. This may be done by passing the fine wire supplied with the pen through the pen point.

i. Insertion of a chart in the recorder is facilitated by tearing off the corners of the paper to provide a point for threading.

j. The center frequency of the crystal-bolometer amplifier is determined by a plug-in filter. Filters are available at any frequency between 500 cps and 2500 cps.

k. Two pattern recorders may be operated from a single bolometer. This procedure is described in the Crystal-Bolometer Amplifier Instruction Manual.

l. Set the chart speed for both MANUAL and AUTOMATIC CHART CYCLE ADVANCE operation to that desired by means of the Manual Speed potentiometer located behind the DEGREES/ CYCLE switch.

m. The PEN-LIFT may be operated by a foot switch to facilitate the control of pattern inking.

n. Use the noise compression circuit to observe side lobes obscured by noise. Do not use the noise compression circuit when noise level reduction is not required.



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# III. DETAILED DESCRIPTION

## 3.1 Construction

The Series APR Rectangular Pattern Recorders are constructed to provide maximum circuit accessibility to facilitate maintenance and adjustment while providing adequate electrostatic and magnetic shielding between sensitive circuits and sources of electric and magnetic fields. Particular attention has been given to interconnecting ground circuits to prevent inter-unit coupling caused by ground loops (See Figure 15).

The two major assemblies of the recorder are designed for mountint on rack slides, and many of the recorder circuits are accessible from the sides when a chassis is in the extended position. All variable components which require only occasional adjustment are provided with lock nuts and are arranged to be accessible from either the front, top or side of the chassis.

Both the sensitive preamplifier and the pen function amplifier are plug-in units housed in shielded cans when in position. The lower shield can which houses the preamplifier is constructed of high permeability material. Both the preamplifier and the pen function amplifier are supplied with regulated dc filament voltages.

The balance potentiometers used with the pen system are housed in self-aligning plug-in cases and allow rapid replacement without the necessity of adjustment.

## 3.2 Preamplifiers

The plug-in preamplifier furnished with the rectangular recorder may be either a crystal-bolometer amplifier, a dc-chopper preamplifier, or both. The crystal-bolometer amplifier permits the recorder pen system to be directly driven from an audio voltage or from a crystal or bolometer detector receiving an audio-modulated r-f carrier. For operation from a crystal detector receiving an unmodulated r-f carrier or from a direct dc input, the dc-chopper preamplifier must be used. This amplifier employs a mechanical chopper to convert an input dc voltage to a 400 cps carrier.

This carrier is fed through a narrow-band amplifier to limit noise.

A complete description of the crystal-bolometer amplifier and the dc-chopper preamplifier will be found in the separate instruction manuals provided with these units.

### 3.3 Pen Function Amplifier

The pen function amplifier is a plug-in unit which provides the necessary amplification and switching to generate one or more recorder pen functions. Five models of this unit are available permitting a wide selection of pen function combinations. The model numbers and pen functions provided are as follows:

| Model | Pen Functions |
|---|---|
| PFA 21 | linear |
| PFA 22 | logarithmic |
| PFA 23 | linear-logarithmic |
| PFA 24 | linear-square root |
| PFA 25 | linear-square root-logarithmic |

A complete description of the pen function amplifier will be found in the Pen Function Amplifier Instruction Manual.

### 3.4 Pen Servo Amplifier

A circuit diagram of the pen servo amplifier will be found at the top of Figure 16 located at the rear of this manual. This amplifier consists of stages V1-1, V2-1, and V3-1, V4-1.

A unipolar dc error voltage is furnished to the input of the pen servo amplifier through pin A of J4-1. This voltage is directly applied to the arm of the chopper (K1-1). This chopper together with T1-1 furnish a 60 cps voltage proportional to the dc input to the grid of the first half of V1-1. Both triodes of V1-1 are resistance-capacitance coupled amplifiers which are cascaded and drive either the GAIN potentiometer (R17-1) when the NOISE COMPRESSION switch (S1-1) is OFF or the input of the noise com-

pression circuit when the NOISE COMPRESSION switch is ON. When S1-1 is in the OFF position, the noise compression circuit is removed and the GAIN potentiometer is coupled to the output of the second half of V1-1 through R14-1, R15-1, and C3-1. The network consisting of R11-1, CR1-1, CR2-1, CR4-1, C4-1, C5-1, and R12-1 is actually a part of the noise compression circuit which is not removed when S1-1 is in the OFF position. This portion of the noise compression circuit, however, has only a slight resistive loading effect on the amplifier output. When S1-1 is in the ON position, the noise compression circuit performs the following functions:

a. The signal coupled to the GAIN potentiometer through R14-1 and R15-1 is limited upon conduction of CR5-1 and CR6-1. These diodes are silicon diodes and conduct only when the applied potential exceeds approximately 0.5 volts. The diodes are paralleled to provide bipolar limiting of the signal. The level of signal normally applied to CR5-1 and CR6-1 is such that conduction occurs at the level of error voltage obtained when the recording pen is displaced by approximately 0.02 inch from a null. In the region nearer the null, full amplifier gain is available providing maximum accuracy. The amplitude of the error signal when limited by conduction of CR5-1 and CR6-1 is determined by the series resistance R16-1. The value of R16-1 is adjusted to provide a maximum recorder pen slewing speed of 2 inches-per-second when the amplitude of the error signal is not permitted to exceed the limited value.

b. A network consiting of R11-1, CR1-1, CR3-1, and R13-1 allows the signal to bypass the limiting circuit upon conduction of CR1-1 and CR3-1. In the bypass state, full error voltage is furnished to the GAIN potentiometer. Diodes CR1-1 and CR3-1 are silicon voltage regulators connected back-to-back to provide bipolar conduction at applied potential levels in excess of 4.5 volts. The normal level of error voltage appearing across these diodes is such that conduction occurs at the level of error voltage present when the recording pen is displaced from a null by ± 1.25 per cent of full scale. Thus, the recorder pen response

is limited only in a selected region about the null. The effect of this amplifier characteristic is to greatly reduce the pen response to rapid signal fluctuations with amplitudes occurring within the limited region.

c. To provide additional noise discrimination, the network consisting of CR2-1, CR4-1, C4-1, C5-1, and R12-1 is employed to enable or disable the bypass circuit. CR2-1 and CR4-1 are germanium diodes which conduct upon application of potential. During conduction of these diodes, the junction between CR-1 and CR3-1 is essentially bypassed to ground and the response of the recorder is again limited by R16-1 and the associated diodes. The diodes CR2-1 and CR4-1 will not conduct if the charges on C4-1 and C5-1 are equal to the peak signal level. The time constant of the network C4-1, R12-1, C5-1, is adjusted to allow C4-1 and C5-1 to fully charge only if several successive cycles of the 60 cps error signal occur. Therefore, for random error voltages such as noise voltages, the capacitors will be unable to completely charge and the pen amplifier response is limited.

The variable arm of the GAIN potentiometer is coupled to the grid of the first half of V2-1. This stage is a summing amplifier with the 60 cps pen tachometer signal applied to its cathode. The error signal and the tachometer signal are combined in this stage and coupled to the grid of the second half of V2-1. This stage is a phase splitter which provides two out-of-phase signals for the push-pull output stage.

The push-pull output stage consisting of V3-1, V4-1, and T2-1 provides the necessary power amplification to drive the 500 ohm control winding of the pen servo motor. The primary of T2-1 is resonated at approximately 60 cps to provide both harmonic rejection and a signal phase shift. A 90-degree phase relationship must exist between the voltage applied to the pen motor reference winding and that applied to the control winding. The reference winding of the pen motor is energized from the ac line. The ac error voltage is initiated by the chopper which is also energized from the ac line. The chopper, however, has an inherent phase lag. This lag together with additional phase lags introduced by the shunt capacitor (C6-1) and by the resonant primary of

T2-1 provide a total signal phase shift of 90 degrees. The secondary of T2-1 provides a 500 ohm output impedance and delivers a maximum power of 14 watts to the control winding of the pen servo motor.

### 3.5 Chart Servo Amplifier

A circuit diagram of the chart servo amplifier will be found at the right center of Figure 16 which is located at the rear of this instruction manual. This amplifier consists of stages V5-1, V6-1, and V7-1, V8-1.

A 60 cps error voltage coupled from the appropriate chart synchro transformer is applied to the GAIN control R33-1. The 60 cps chart tachometer signal is applied to the TACHOMETER control (R31-1). These two voltages are summed by a resistive network (R34-1 and R32-1) and are applied to the grid of V5-1. V5-1 is a resistance-capacitance coupled amplifier with C13-1 shunting the output to limit the high frequency response and suppress oscillation. V6-1 is a phase-splitting amplifier which drives the push-pull power amplifier consisting of V7-1, V8-1, and T3-1. The primary of T3-1 is resonated at approximately 60 cps to provide both harmonic rejection and a signal phase shift. A 90-degree phase relationship must exist between the voltage applied to the chart motor reference winding and that applied to the control winding. The voltages for both the motor reference winding and the synchro transmitter rotor winding are obtained from the power line and are in phase. It is therefore necessary to provide a 90-degree phase shift in the chart servo amplifier. This is accomplished by phase leads introduced by the coupling network (C14-1, R38-1, and C13-1) and by the resonant primary of T3-1. The secondary of T3-1 provides a 500-ohm output impedance and delivers a maximum power of 14 watts to the control winding of the chart servo motor.

### 3.6 Power Supplies

The circuit diagrams of the plate and filament power supplies for the rectangular pattern recorder are shown on Figure 16 which is located at the rear of this manual.

The power supply consisting of T4-1, V9-1, and the associated

filter is a 285 volt, 200 ma power supply which furnishes plate potential to the push-pull power amplifiers in both the pen servo amplifier and the chart servo amplifier.

The high voltage winding of T5-1, the rectifier (V10-1), and the associated filter provide dc potential to the 250 volt regulator. This regulator consists of the series tube (V11-1), the balanced amplifiers (V12-1 and V14-1), and the reference tube (V13-1). The regulator delivers a 250 volt, 70 ma output which is furnished to all recorder amplifiers. The 150 volt potential across the regulator tube (V13-1) is employed as a potentiometer reference voltage source in the pen function amplifier and as a bolometer bias voltage source in the crystal-bolometer amplifier.

A transistor-regulated filament supply provides a 12 v dc filament voltage for the preamplifier and the pen function amplifier. This supply employs a selenium bridge rectifier operating from the 15 volt winding of T5-1. The regulator consisting of series transistor (Q1-1), ballast lamp (RT1-1), and zener diode CR8-1 delivers an output current of 1 ampere. R63-1 permits adjustment of the level of output voltage furnished by this supply.

## 3.7 Pen Drive Mechanical System

The pen drive servo motor (A, Figure 10) drives the potentiometer (B, Figure 10) and the pen cable drum (C, Figure 10) through a precision gear and pinion assembly (D, Figure 10). The rotary motion of the pen cable drum is converted to linear motion across the chart writing surface by the nylon pen drive cable. Stops (E, Figure 10) limit the rotation of the pen cable drum and thus limit the cable travel to a distance slightly greater than the length of the chart scale.

The recording pen holder is fastened to the drive cable with the pen point placed 1/16 inch below the lower end of the calibrated chart when the pen cable drum is fully clockwise against the stop. The glass inking pen is held in place in the holder by two spring clips and a point positioning guide.

The recording pen is switched between the LIFT and the WRITE positions by an eccentric bar (A, Figure 11). This lift bar is moved to a position clear of the pen holder when it is rotated by the pen lift solenoid

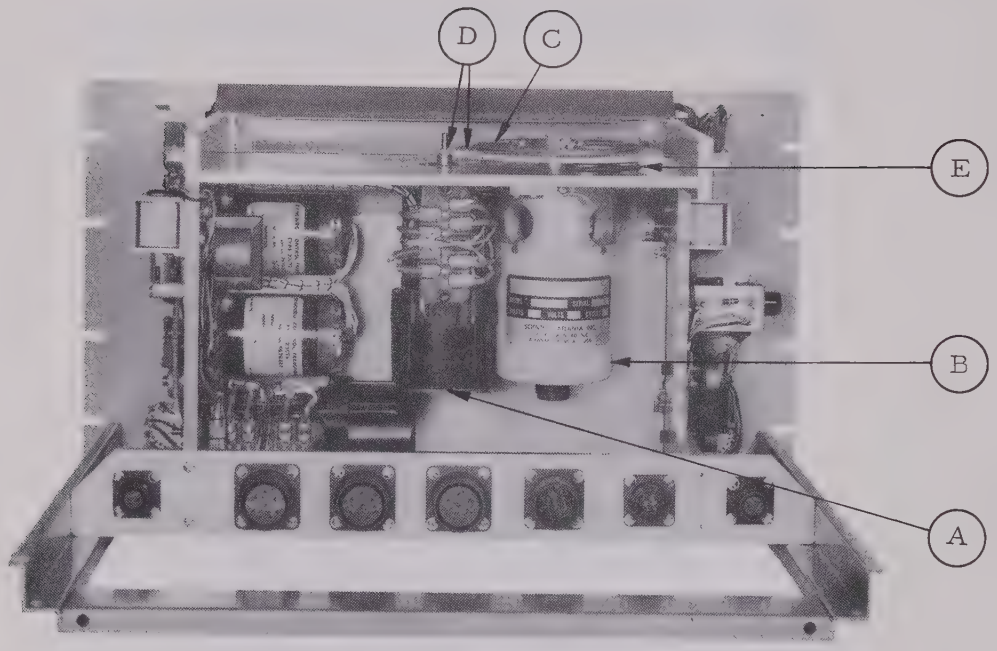



Figure 10. Rear View of Rectangular Pattern Recorder Head.

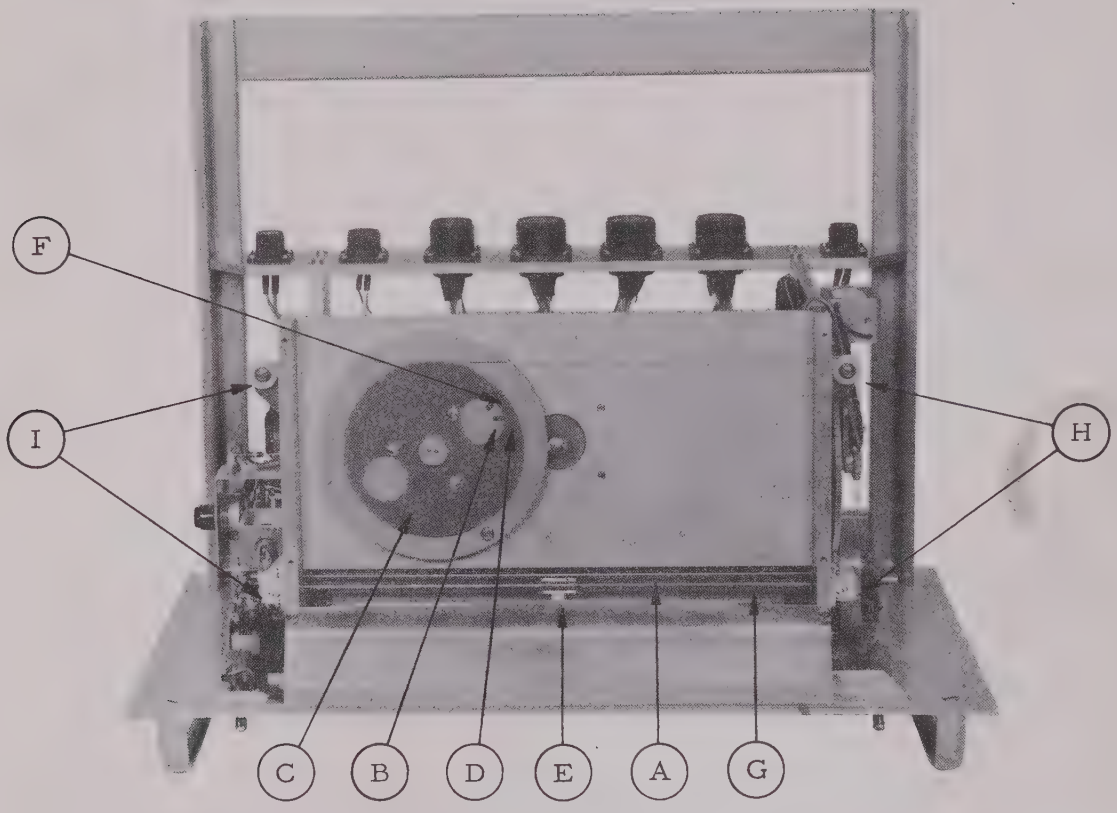



Figure 11. Top View of Rectangular Pattern Recorder Head.

(A, Figure 12). In this case, the weight of the pen and pen holder causes the pen to drop and contact the chart surface. When the solenoid is de-energized, the pen lift spring (B, Figure 12) rotates the pen lift bar to lift and hold the pen in the LIFT position.

## 3.8 Chart Drive Mechanical System

The chart roll is supported between the right disc (A, Figure 13) which is spring loaded to provide constant contact and the left disc (B, Figure 13) which is keyed to assure rotation with the chart roll. The left disc is geared to the rewind motor (C, Figure 12) which maintains constant tension on the chart paper. This motor will withstand continuous stalling without damage.

During operation, the chart is fed behind and over the sprocketed chart drive cylinder (C, Figure 8) and under the chart hold-down clips (C and D, Figure 13). The chart drive cylinder is driven by the gear train located outside the right end-plate. This gear train consists of the chart servo motor pinion (A, Figure 14) which drives the large gear and pinion (B, Figure 14) coupled to the 1 to 6 synchro transformer. This pinion coupled to the 1 to 6 synchro transformer drives the large gear (C, Figure 14) coupled to the 1 to 1 synchro transformer, which then drives the chart drive gear which is behind the clutch cover plate (D, Figure 14).

Coupling between the chart drive cylinder and the chart drive gear is through a clutch plate. Pressure on the clutch plate is provided by a coil spring (D, Figure 12). This spring clutch arrangement permits the chart to be adjusted to any desired position with respect to the synchro transformers. This adjustment is made with the CHART ZERO knob which, when depressed, engages a bevel gear (E, Figure 14) coupled to the chart drive cylinder.

## 3.9 Control Circuits

Figure 17 is a diagram of the circuits associated with the recorder head assembly. This chassis contains the circuits for the servo motors and synchro transformers of the chart system and pen system.

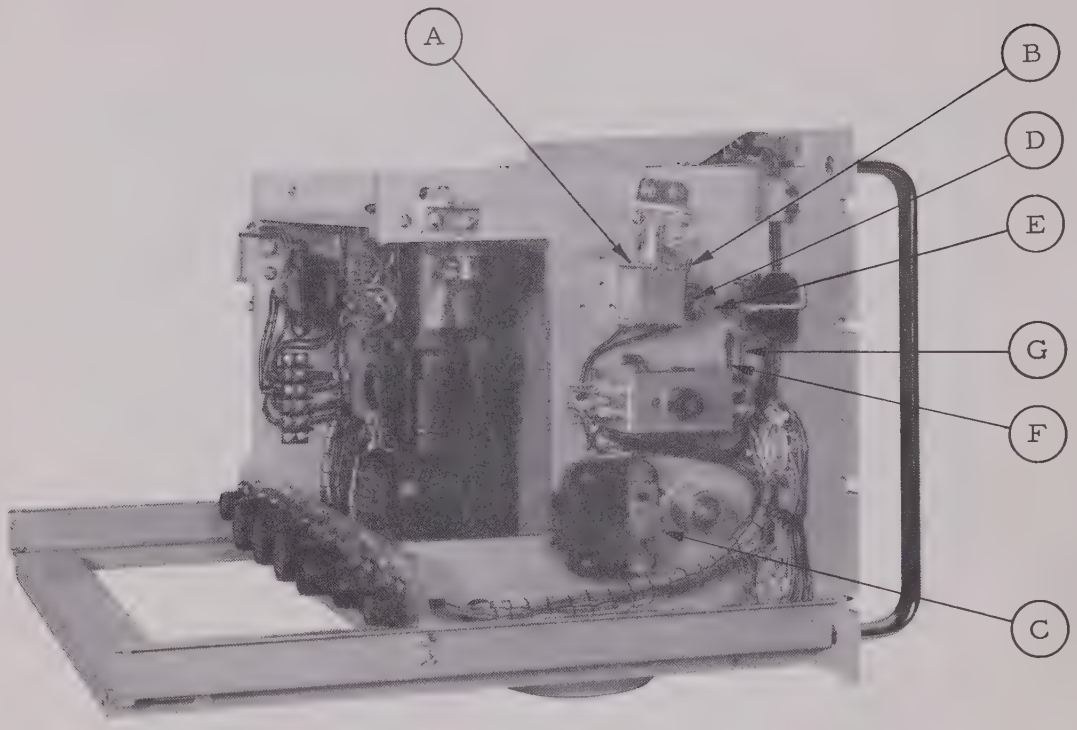



Figure 12. Left Side View of Rectangular Pattern Recorder Head showing Pen Lift Solenoid Assembly.

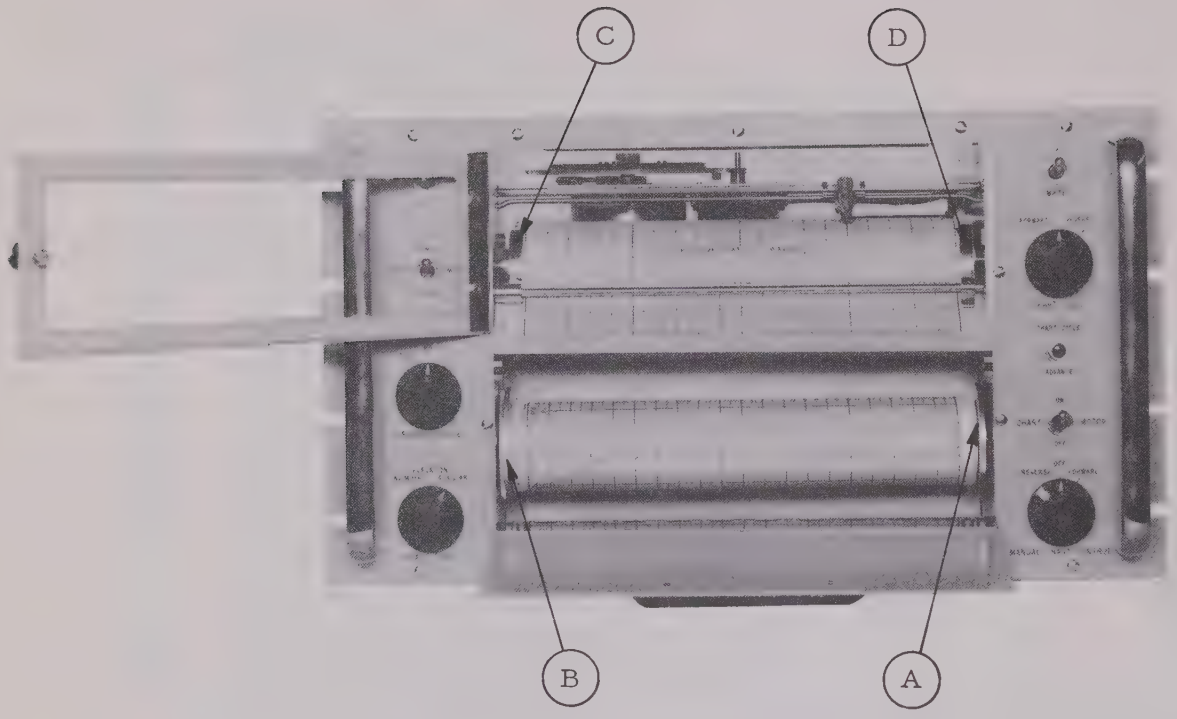



Figure 13. Front View of Rectangular Pattern Recorder Head with Chart Installed.

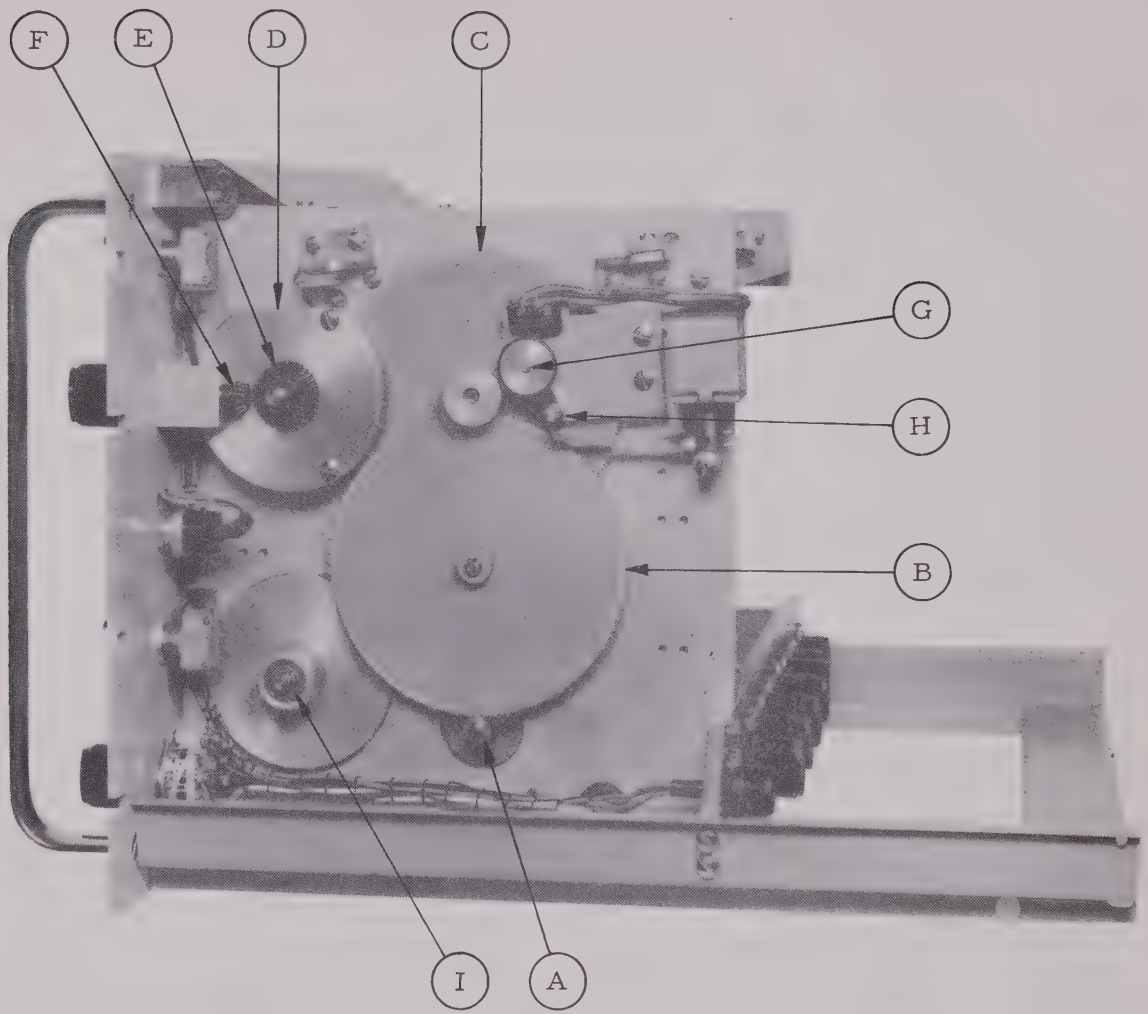



Figure 14. Right Side View of Rectangular Pattern Recorder Head.

ON-OFF switching of the pen drive motor and the chart drive motor is provided by S2-4 and S3-4 respectively. A remote switch for ON-OFF control of the pen motor may be connected to J4-4. For remote operations the PEN MOTOR switch must be in the OFF position.

Any one of three synchro inputs may be selected by the CHART DRIVE switch (S4-4). Chart scale expansion is provided by the DEGREES/CYCLE switch (S5-4) and reversal of the chart direction is accomplished by the CHART MOTION switch (S6-4).

The LIFT-WRITE switch (S1-4) energizes a solenoid (L1-4) when in the WRITE position allowing the pen to contact the chart surface. With this switch in the LIFT position, a foot switch connected to J2-4 will permit foot control of the pen writing.

The MANUAL CHART CONTROL switch (S7-4) permits either forward or reverse chart drive at a constant speed. This speed is determined by adjustment of the MANUAL SPEED potentiometer (R2-4).

Depressing the CHART CYCLE ADVANCE button (S8-4) energizes solenoid L2-4 and relay K1-4. Closure of the relay (K1-4) causes a constant error voltage to be applied to the input of the chart servo amplifier. The magnitude of this error voltage is set by the MANUAL SPEED potentiometer (R2-4) and provides chart rotation at the same speed as that obtained during operation of the MANUAL CHART CONTROL switch. Operation of the solenoid (L2-4) causes a friction drive wheel (G, Figure 14) to rotate the attached chart cycle advance disc at a rate of one revolution per chart cycle. As the disc rotates, S9-4 closes maintaining L2-4 and K1-4 in the energized state. The relay and the solenoid remain energized until the chart cycle advance disk completes one revolution. At this time S9-4 opens removing the voltage from the solenoid and the relay. When the relay drops out the input to the chart servo amplifier is reconnected to the servo system. This results in an automatic chart advance of exactly one cycle. When initiating the automatic advance cycle, S8-4 must remain depressed until S9-4 closes.

# IV. ADJUSTMENTS

## 4.1 Chart Drive System

### 4.1.1 Chart Zero Clutch:

The CHART ZERO control operates through a friction clutch which allows the chart drive cylinder (C, Figure 8) to be rotated with respect to the reference synchro transformers. If the clutch tension is too tight, difficulty will be encountered when attempting to adjust the chart; if the clutch tension is too loose, slippage between the chart and the chart position control system will occur.

The clutch tension is determined by the combination of adjustments of the hexagon nut (E, Figure 12) located at the left end and a second nut located on the right end of the shaft supporting the chart drive cylinder. A balanced adjustment of these two nuts will give correct clutch motion and clutch tension.

### 4.1.2 Chart Hold-Down Clips:

The chart is held in position at each end of the chart drive cylinder by a chart hold-down clip (C or D, Figure 13) which is curved and slotted to fit over the sprocket and contact the paper on both sides of the sprocket. These two hold-down clips are independently spring-loaded to provide positive paper contact at both ends of the chart drive cylinder.

Spring tension on the left hold-down clip is provided by a spring and collar (F, Figure 12). Spring tension on the right hold-down clip is provided by a spring (G, Figure 12) which tends to rotate the hold-down clip support bar (G, Figure 8). The adjustment of the right hold-down clip may be altered by loosening the set screw which locks the clip to the support bar. Positioning of the right hold-down clip about the axis of the support bar should be such that it will lift 1/16 inch above the chart surface before the left clip is engaged. The right clip should be carefully centered over the sprocket to prevent contacting the sprocket projections.

## 4.2 Pen Drive System

### 4.2.1 Pen Drive Cable:

The pen drive cable is type 10-X limp nylon cord. The length of the installed cable is approximately 60.5 inches. Both ends of the cable are terminated in slots located in the drive drum, the ends being secured by small crimped sleeves (B, Figure 11).

To enable installation of a new pen drive cable, remove the cover from the pen drive assembly, remove the old cable and rotate the cable drive drum (C, Figure 11) fully clockwise. This cable should be at least 60.5 inches long and should have a sleeve crimped on the starting end. Place the cable in the slot (D, Figure 11) with the sleeve at the inside. Feed the cable clockwise around the drive drum and over the two idler pulleys (H, Figure 11) mounted on the right-hand end plate. (Holes are provided in the end plate for the cable). Guide the cable across the front of the writing compartment and insert the cable under the metal plate located at the top of the pen holder (E, Figure 11). (Loosen the two screws at the top of the pen holder for this operation and do not retighten until cable installation is complete.) Feed the cable over the two idler pulleys ( I, Figure 11) located on the left-hand end plate and then back to the drive drum. Wrap the cable one and one-half times clockwise about the drive drum while stretching the cable approximately one-half inch. Secure the end terminated with a crimped sleeve into the remaining slot (F; Figure 11). The pen holder should be tightened on the cable with the pen position 1/16 inch below the chart scale when the drive drum is fully clockwise against the stop.

### 4.2.2 Pen LIFT-WRITE Adjustment:

The pen LIFT-WRITE operation is accomplished by the motion of the eccentric lift rod ( A, Figure 11) located behind and below the pen slide bar ( G, Figure 11). The pen lift solenoid ( G, Figure 9) is energized in the WRITE position causing the eccentric lift rod to clear the rear of the pen holder assembly by approximately 1/32 inch when the pen is contacting the chart surface.

If adjustment of the pen lift rod is required, loosen the set screw in the lift cam (F, Figure 9) and adjust the lift rod for a 1/32 inch clearance with respect to the pen holder with the pen lift solenoid energized. Retighten the set screw.

## 4.3 Power Supplies

Two of the three power supplies in the pattern recorder are regulated and have voltage adjustment potentiometers which determine the levels of voltage output. Both of these adjustments are locked and require only occasional resetting.

To adjust the output level of the 12 volt dc filament supply, measure the voltage at test jacks provided (TP5-1 and TP6-1, black positive and blue negative) and adjust R63-1 for 12 ± 1 volt. The recorder will perform satisfactorily at any dc filament voltage level within this range.

The output of the 250 volts dc supply may be measured between TP3-1 and TP4-1. This voltage is adjusted by R6-1 and should be set to 250 ± 5 volts.

## 4.4 Chart Servo Amplifier

The GAIN and TACHOMETER controls of the chart amplifier should be adjusted for maximum servo loop tightness and for critical damping. A measure of loop tightness is the ability of the chart to return to the same null after being displaced from the null in either direction. Damping is measured by the ability of the chart to abruptly cease motion. Critical damping is obtained when the chart stops upon a servo command without noticeable overshoot or undershoot of the null point.

To permit adjustment of the chart system GAIN and TACHOMETER controls, connect the chart system to suitable synchro generators and place the DEGREES/CYCLE switch in the 10-degree position. Turn both the GAIN and TACHOMETER controls fully counterclockwise, then turn the TACHOMETER control approximately 1/4 turn clockwise. With the CHART MOTOR switch ON, advance the GAIN control clockwise until the chart system is

nulled. Use the CHART ZERO control to align the pen with one of the angle lines on the chart. The GAIN control should now be set to provide the minimum value of gain which causes the pen to return to the reference line after the chart is forcibly displaced either side of the null. Displacement of the chart from null can be accomplished by manually rotating the chart forward or backward with the fingers or by rotating one of the chart drive gears located at the right side of the recorder head assembly.

The TACHOMETER control may now be set for critical damping. A step function should be applied to the chart drive system by operating the CHART MOTION switch. When applying this step function, observe chart overshoot or undershoot as the chart approaches the null. The TACHOMETER should be adjusted such that the chart approaches the null point at a steady rate of speed and stops without overshooting or undershooting. Undershoot is indicated by a noticeable reduction of chart speed as the null position is approached.

## 4.5 Pen Servo Amplifier

Three pen servo amplifier adjustments are provided which determine the response of the recording pen when either a logarithmic or square-root pen function is used; these are the GAIN, TACHOMETER, and DAMPING CORRECTION controls. When only a linear pen function is provided, the DAMPING CORRECTION is not used.

When a pattern recorder has more than one pen function, it is necessary to adjust the pen servo amplifier controls for a particular response to provide proper adjustment for all pen responses. For the several models of the pattern recorder, the servo amplifier adjustments for each model should be made with the recorder set to the pen function indicated by the following table:

TABLE I Pen Function For Servo Amplifier Adjustment

| Recorder Model | Pen Function | Perform Adjustments Using Pen Function Below: |
|---|---|---|
| APR 21 | Linear | Linear |
| APR 22 | Logarithmic | Logarithmic |
| APR 23 | Linear - Logarithmic | Logarithmic |
| APR 24 | Linear - Square Root | Square Root |
| APR 25 | Linear - Log. - Sq. Root | Logarithmic |

The procedure for pen servo amplifier adjustment follows:

a. Determine the proper pen function from TABLE I and connect recorder accordingly.

b. Turn the pen servo amplifier GAIN and TACHOMETER controls fully counterclockwise. Set TACHOMETER 1/4 turn clockwise.

c. If recorder response is non-linear (logarithmic or square-root), turn the DAMPING CORRECTION control located on the pen function amplifier fully counterclockwise.

d. Set ATTENUATOR on preamplifier to 20 and apply signal to INPUT.

e. Turn pen servo amplifier GAIN control clockwise until pen nulls. Set signal level for approximately 1/2 scale pen deflection. NOISE COMPRESSION switch must be OFF.

f. Deflect the pen to either side of null with finger to observe servo loop tightness. Set pen servo amplifier GAIN control to minimum value of gain required for the pen to return to an accurate null.

g. Switch ATTENUATOR on preamplifier between 20 db and 30 db positions to introduce pen steps. Set the TACHOMETER control to allow a pen overshoot of approximately 1/8 inch for a down-scale pen step. For logarithmic and square-root pen functions, the overshoot will be higher on the upscale pen step.

h. If the pen function is logarithmic or square-root, turn the DAMPING CORRECTION control located on the pen function ampli-

fier to equalize the overshoot on the upscale and downscale pen steps. If the pen function is linear disregard this step.

i. Readjust the TACHOMETER control for minimum pen overshoot and undershoot of the null point.

# V. SERVICE AND MAINTENANCE INSTRUCTIONS

## 5.1 General Procedures

In the event of faulty operation of any part of the pattern recorder, a visual inspection of tubes, cable connections, and other components should be completed first. Afterward, standard maintenance procedures should be followed to isolate the trouble to a particular stage and then to the defective component. To aid in the maintenance, the circuit diagram provides typical plate voltage and current values, component values, and parts numbers. In addition, voltage and gain tables are furnished to serve as a guide for testing the static and dynamic circuit operation. Similar tables for the preamplifiers and pen function amplifer are furnished in separate instruction manuals.

## 5.2 Static Measurements

The following table provides typical values of voltages present at the tube pins of the amplifier stages. These voltages are measured with respect to ground (TP4-1) using a 20,000 ohm-per-volt dc voltmeter and a 1,000 ohm-per-volt ac voltmeter. These voltages are subject to standard tolerances of ± 10%. During measurement, both the recording pen system and the chart system should be nulled.

TABLE II DC and RMS AC Voltages

| Tube or Transistor Number | Tube or Transistor Pins | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Base 1 | Emitter 2 | Collector 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| V1-1 | 65 | 0 | 1.8 | 6.3 ac | 6.3 ac | 100 | 0 | 1.6 | 0 |
| V2-1 | 81 | 0 | 0.8 | 6.3 ac | 6.3 ac | 157 | 81 | 86 | 0 |
| V3-1 | 6.3 ac | 265 | 285 | -- | -- | 0 | 17 | 0 | -- |
| V4-1 | 6.3 ac | 265 | 285 | -- | -- | 0 | 17 | 0 | -- |
| V5-1 | 62 | -- | 6.3 ac | 0 | 62 | 0 | 1.8 | -- | -- |
| V6-1 | 208 | 0 | 13.2 | 6.3 ac | 6.3 ac | 213 | 0 | 13.2 | 0 |
| V7-1 | 6.3 ac | 265 | 285 | -- | -- | 0 | 17 | 0 | -- |
| V8-1 | 6.3 ac | 265 | 285 | -- | -- | 0 | 17 | 0 | -- |
| V9-1 | -- | 305 | -- | 300 ac | -- | 300 ac | -- | 305 | -- |
| V10-1 | -- | 410 | -- | 345 ac | -- | 345 ac | -- | 410 | -- |
| V11-1 | 400 | 247 | 250 | -- | -- | 250 | 247 | 3 | 400 |
| V12-1 | 247 | 85 | 86 | 6.3 ac | 6.3 ac | 250 | 85 | 86 | 0 |
| V13-1 | 150 | 0 | -- | 0 | 150 | -- | 0 | -- | -- |
| V14-1 | 85 | 33 | 35 | 6.3 ac | 6.3 ac | 250 | 32 | 35 | 0 |
| Q1-1 | -12.6 | -12.3 | -17.7 | -- | -- | -- | -- | -- | -- |

## 5.3 Dynamic Measurements

The following table provides typical values of voltage-gain-per-stage for the amplifiers located on the amplifier and power supply chassis. A signal may be applied to either the pen servo amplifier or the chart servo amplifier to permit gain measurement by manually displacing the recording pen or the chart roll from a null with the servo motors off. Only a slight displacement from null should be introduced to prevent amplifier saturation. NOISE COMPRESSION should be OFF and pen servo amplifier GAIN control set fully clockwise.

TABLE III 60 cps Gain

| Gain Measured | | Voltage Gain |
|---|---|---|
| From | To | |
| Pin 2, V1-1 | Pin 1, V1-1 | 14 |
| Pin 1, V1-1 | Pin 6, V1-1 | 27 |
| Pin 6, V1-1 | Pin 1, V2-1 | 4 |
| Pin 1, V2-1 | Pin 6, V2-1 | 0.9 |
| Pin 6, V2-1 | Pin 2, V3-1 | 23 |
| Pin 8, V2-1 | Pin 2, V4-1 | 23 |
| Pin 6, V2-1 | Pin C to D, J1-1 | 11 |
| Pin 6, V5-1 | Pin 1, V5-1 | 14 |
| Pin 1, V5-1 | Pin 1, V6-1 | 1.5 |
| Pin 1, V5-1 | Pin 1, V6-1 | 2.2 |
| Pin 6, V6-1 | Pin 2, V7-1 | 22 |
| Pin 1, V6-1 | Pin 2, V8-1 | 22 |
| Pin 6, V6-1 | Pin G to H, J3-1 | 11 |

The peak-to-peak ripple present at the output of each of the three dc power supplies is shown by Table IV. To maintain a minimum of hum in the pen amplifier signal channel, these hum levels should be less than the values shown with full load on the power supplies and servo loops nulled.

TABLE IV Power Supply Ripple

| Power Supply Voltage (dc) | Peak-to-Peak Ripple |
|---|---|
| 12 | 0.5 volts |
| 250 | 10 millivolts |
| 285 | 3 volts |

5.4 Plug-in Potentiometer Phasing

The plug-in potentiometers are factory adjusted for proper alignment with the pattern recorder when properly installed in place. In the event a plug-in potentiometer is disassembled, the following alignment procedure should be followed to assure proper operation:

a. Remove cover from pen drive assembly and rotate drive gear (C, Figure 11) fully clockwise against stop.
b. With the potentiometer drive gear against the stop, the recording pen should be positioned approximately 1/16 inch below lower end of chart scale. If this is not the case, loosen the pen assembly mounting screws (E, Figure 11) and properly position the pen on the cable; then tighten screws.
c. With the plug-in potentiometer in place in the recorder, position the recording pen to the stop position at the left of the chart scale. The proper potentiometer element phasing may be determined by resistance measurements made with the pattern recorder OFF and with P3-2 (potentiometer cable connector) disconnected from the pen function amplifier. These resistance measurements are made between the pins of P3-2 as shown by the following table:

TABLE V Potentiometer Phasing Data

| Plug-in Potentiometer Model Number | Potentiometer Function | Potentiometer Element Location | Measure Between P3-2 Pins: | Phase Potentiometer for Resistance of: |
|---|---|---|---|---|
| P-1 | Linear | --- | A to F | 100 ± 25 ohms |
| P-2 | Linear<br>Square-root | Upper<br>Lower | A to F<br>C to D | 100 ± 25 ohms<br>5 to 10 ohms |
| P-3 | Logarithmic (40 db) | --- | D to E | 175 ± 25 ohms |
| P-3-2 | Logarithmic (20 db) | --- | D to E | 100 ± 25 ohms |
| P-4 | Logarithmic (60 db) | --- | D to E | 175 ± 25 ohms |

The preceding resistance measurements must be made with the potentiometer drive gear fully clockwise against the stop (pen set 1/16 inch below chart scale). To phase a potentiometer element, the outer case must first be removed; then the potentiometer element lock ring loosened to permit rotation. When the plug-in potentiometer unit consists of two potentiometer elements ganged together, the upper unit must be phased first and locked before phasing of the lower unit is attemped.

It is possible in some cases to set the potentiometer element for the proper resistance value but on the wrong side of the break or null (zero resistance). After a potentiometer element is phased and locked to provide the proper resistance measurements, the pen should be slowly moved upscale while observing the resistance change. For all potentiometer elements, this resistance should continually increase indicating that the break or null does not occur within the limits of pen motion.

In the case of a square-root potentiometer element, best response is obtained with the break occurring as close to the lower scale pen stop position as possible.

After phasing a logarithmic potentiometer element, an additional check should be made. Measure the resistance between pins E and F of P3-2 and set the recording pen upscale against the stop. Moving the pen downscale from the stop should provide an increasing value of resistance. If a jump or discontinuity occurs, the potentiometer element should be positioned to move

the discontinuity just outside the upper scale limit of the pen excursion.

## 5.5 Mechanical Components

All anti-friction bearings used in the assembly of the Series APR 20 Rectangular Recorder Head are precision bearings (ABEC-1 or better) and are furnished with seals and permanent lubrication. These bearings should require no maintenance or lubrication during the normal life of the recorder. The only part requiring frequent lubrication is the pen slide bar (G, Figure 11). One or two drops of light machine oil should be applied to this bar at least once a week to minimize wearing of the pen holder bearings.

Other points which should be lubricated with light machine oil at least once every three months are as follows:

a. (F, Figure 14) Shaft of CHART ZERO knob.
b. (G, Figure 14) Shaft of cycle cam.
c. (H, Figure 14) Shoulder screw of cycle cam support.
d. (I, Figure 14) Shaft of right chart roll disk.
e. (A, Figure 11) Each end of eccentric pen lift bar.
f. (G, Figure 8) Each end of chart hold-down support bar.

PARTS LIST

POLAR PATTERN RECORDER

MANUFACTURERS' CODE LETTERS

| Code | Manufacturer |
|---|---|
| A | Aerovox Corporation |
| AE | Amphenol Electronics Corporation |
| AP | Airpax Products Company |
| AX | Amperex-Electronics Corporation |
| BAR | Barber-Colman Company |
| BUS | Bussman Manufacturing Division - McGraw-Edison Co. |
| C | Chicago Standard |
| CD | Cornell-Dubilier Electric Corporation |
| CH | Cutler-Hammer, Incorporated |
| CRL | Centralab Division of Globe Union, Incorporated |
| DM | Diehl Manufacturing Company |
| DPD | Delco Products Division - General Motors Corporation |
| G | Grayhill, Incorporated |
| GC | General Cement Manufacturing Company |
| GE | General Electric Company |
| HH | Hubbell, Harvey, Incorporated |
| L | Littelfuse, Incorporated |
| MS | Micro Switch Division - Minneapolis Honeywell |
| O | Ohmite Manufacturing Company |
| OE | Osborn Electric |
| PB | Potter & Brumfield, Incorporated |
| PMC | Phillips Control Corporation |
| PY | Pyramid Electronic Corporation |
| SA | Scientific-Atlanta, Incorporated |
| ST | Sarkes Tarzian, Incorporated |
| SY | Sylvania |
| T | Triad Transformer Corporation |
| TE | Transitron Electronic Corporation |

MANUFACTURERS CODE LETTERS - continued

| Code | Manufacturer |
|---|---|
| TO | Tru-Ohm Products Division<br>Monel Engineering & Manufacturing, Incorporated |
| USC | U. S. Semcor |
| VER | Vernitron Corporation |

PARTS LIST

SERIES APR 20/30

AMPLIFIER AND POWER SUPPLY

| Component Designation | Description | Mfr.* | Mfr. Part No. |
|---|---|---|---|
| C1-1 | Capacitor: fixed, paper 0.01 µfd, 400 V DCW | CD | WMF 451E |
| C3-1 C4-1 C5-1 | Capacitor: fixed, tubular 0.047 µfd, 400 V DCW | CD | WMF 4547E |
| C6-1 | Capacitor: fixed, paper 0.01 µfd, 400 V DCW | CD | WMF 451E |
| C7-1 C8-1 | Capacitor: fixed, tubular 0.047 µfd, 400 V DCW | CD | WMF 4547E |
| C9A/B-1 | Capacitor: fixed, electrolytic 10-10 µfd, 450 V DCW | A | AFH 2-47 |
| C10-1 | Capacitor: fixed, bathtub, paper 2 x 0.2 µfd, 600 V DCW | PY | 2PDMR 6-P2 |
| C11-1 | Capacitor: fixed, electrolytic 25 µfd, 25 V DCW | A | PWE 25025 |
| C12A/B-1 | Capacitor: fixed, electrolytic 10-10 µfd, 450 V DCW | A | AFH 2-47 |
| C13-1 | Capacitor: fixed, paper 0.001 µfd, 400 V DCW | A | P488N |
| C14-1 | Capacitor: fixed, paper 0.01 µfd, 400 V DCW | A | P488N |
| C15-1 C16-1 | Capacitor: fixed, paper 0.05 µfd, 400 V DCW | A | P488N |
| C17-1 | Capacitor: fixed, electrolytic 25 µfd, 25 V DCW | A | PWE 25025 |
| C18-1 | Capacitor: fixed, bathtub, paper 0.25 µfd, 600 V DCW | A | JP630M |
| C19A/B-1 C20A/B-1 | Capacitor: fixed, electrolytic 10-10 µfd, 500 V DCW | A | AFH 2-67 |
| C21-1 | Capacitor: fixed, paper 0.1 µfd, 400 V DCW | A | P488N |

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST - continued

AMPLIFIER AND POWER SUPPLY

| Component Designation | Description | Mfr.* | Mfr. Part No. |
|---|---|---|---|
| C22-1 | Capacitor: fixed, paper 0.01 μfd, 400 V DCW | A | P488N |
| C23-1 | Capacitor: fixed, electrolytic 1000 μfd, 25 V DCW | A | AFH1-10 |
| C24-1 C25-1 | Capacitor: fixed, electrolytic 500 μfd, 25 V DCW | A | AFH 1-08 |
| CR1-1 | Diode: silicon | TE | SV 804 |
| CR2-1 | Diode: crystal | TE | 1N277 |
| CR3-1 | Diode: silicon | TE | SV 804 |
| CR4-1 | Diode: crystal | TE | 1N277 |
| CR5-1 CR6-1 | Diode: silicon | TE | S4G |
| CR7-1 | Rectifier: selenium bridge | ST | 604B |
| CR8-1 | Diode | USC | 1N1354A |
| DS1-1 | Bulb: incandescent, 6.3V, bayonet | GE | 47 |
| F1-1 | Fuse: type 3AG, 1.5 amperes | L | 31201.5 |
| F2-1 | Fuse Holder: panel mounting | BUS | HKP |
| F3-1 | Fuse: type 3AG, 3 amperes | L | 312003 |
| | Fuse Holder: panel mounting | BUS | HKP |
| F4-1 | Fuse: type 3AG, 1.5 amperes | L | 31201.5 |
| | Fuse Holder: panel mounting | BUS | HKP |
| J1-1 | Connector | AE | 97-3102A-14S-2S |
| J2-1 | Connector: AC | HH | 7255 |
| J3-1 | Connector | AE | 97-3102A-18-8S |
| J4-1 | Connector | AE | 97-3102A-18-19S |
| J5-1 | Connector | AE | 97-3102A-18-1S |
| J9-1 | Connector: miniature | AE | 165-14 |
| J10-1 | Connector: miniature | AE | 165-10 |
| K1-1 | Chopper: AC-DC, SPDT | AP | 175 |
| L1-1 | Choke: filter | C | RH 12200 |
| L2-1 | Choke: filter | C | RH 1585 |
| P6-1 | Connector: AC, power | HH | 7486 |
| P7-1 | Connector | AE | 97-3106A-18-19P |
| P8-1 | Connector | AE | 97-3106A-18-1P |
| Q1-1 | Transistor: power, type PNP | DPD | 2N441 |
| R1-1 R2-1 | Resistor: fixed, composition 10 k ohms, 10%, 1/2 watt | O | "Little Devil" |

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST, Continued

AMPLIFIER AND POWER SUPPLY

| Component Designation | Description | Mfr.* | Mfr. Part No. |
|---|---|---|---|
| R3-1 | Resistor: fixed, composition 10 ohms, 10%, 1/2 watt | O | "Little Devil" |
| R4-1 | Resistor: fixed, composition 33 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R5-1 | Resistor: fixed, composition 10 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R6-1<br>R7-1 | Resistor: fixed, composition 1 m ohm, 10%, 1/2 watt | O | "Little Devil" |
| R8-1 | Resistor: fixed, composition 470 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R9-1 | Resistor: fixed, composition 1 k ohm, 10%, 1/2 watt | O | "Little Devil" |
| R10-1 | Resistor: fixed, composition 100 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R11-1 | Resistor: fixed, composition 270 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R12-1 | Resistor: fixed, composition 4.7 m ohms, 10%, 1/2 watt | O | "Little Devil" |
| R13-1 | Resistor: fixed, composition 270 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R14-1<br>R15-1 | Resistor: fixed, composition 470 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R16-1 | Resistor: fixed, composition 68 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R17-1 | Resistor: variable, composition 250 k ohms, 2 watts | O | CLU-2541 |
| R18-1 | Resistor: fixed, composition 470 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R19-1 | Resistor: fixed, composition 4.7 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R20-1 | Resistor: fixed, composition 1 m ohm, 10%, 1/2 watt | O | "Little Devil" |
| R21-1<br>R22-1 | Resistor: fixed, composition 82 k ohms, 10%, 1/2 watt | O | "Little Devil" |

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST, Continued

AMPLIFIER AND POWER SUPPLY

| Component Designation | Description | Mfr.* | Mfr. Part No. |
|---|---|---|---|
| R23-1<br>R24-1 | Resistor: fixed, composition<br>470 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R25-1 | Resistor: fixed, composition<br>100 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R26-1<br>R27-1 | Resistor: fixed, composition<br>47 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R28-1 | Resistor: fixed, composition<br>1 k ohm, 10%, 1 watt | O | "Little Devil" |
| R29-1 | Resistor: fixed, axial lead, ww<br>200 k ohms, 3 watts | TO | VAL-3 |
| R30-1 | Resistor: variable, composition<br>1 k ohm, 2 watts | O | CLU-1021 |
| R31-1 | Resistor: variable, composition<br>25 k ohms, 2 watts | O | CLU-2531 |
| R32-1 | Resistor: fixed, composition<br>330 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R33-1 | Resistor: variable, composition<br>25 k ohms, 2 watts | O | CLU-2531 |
| R34-1 | Resistor: fixed, composition<br>100 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R35-1 | Resistor: fixed, composition<br>2.2 k ohms, 10%, 1 watt | O | "Little Devil" |
| R36-1 | Resistor: fixed, composition<br>100 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R37-1 | Resistor: fixed, composition<br>1 k ohm, 10%, 1/2 watt | O | "Little Devil" |
| R38-1 | Resistor: fixed, composition<br>47 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R39-1 | Resistor: fixed, composition<br>15 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R40-1 | Resistor: fixed, composition<br>47 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R41-1 | Resistor: fixed, composition<br>100 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R42-1<br>R43-1 | Resistor: fixed, composition<br>470 k ohms, 10%, 1/2 watt | O | "Little Devil" |

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST, Continued

AMPLIFIER AND POWER SUPPLY

| Component Designation | Description | Mfr.* | Mfr. Part No. |
|---|---|---|---|
| R44-1 | Resistor: fixed, composition 100 ohms, 10%, 1/2 watt | O | "Little Devil" |
| R45-1 | Resistor: fixed, ww 200 ohms, 5 watts | TO | FRL-5 |
| R46-1 | Resistor: fixed, composition 100 k ohms, 10%, 1 watt | O | "Little Devil" |
| R47-1 | Resistor: fixed, composition 1 m ohm, 10%, 1/2 watt | O | "Little Devil" |
| R48-1<br>R49-1 | Resistor: fixed, composition 47 ohms, 10%, 1/2 watt | O | "Little Devil" |
| R50-1 | Resistor: fixed, composition 68 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R51-1 | Resistor: fixed, composition 100 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R52-1 | Resistor: fixed, composition 82 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R53-1 | Resistor: fixed, axial lead, ww 3 k ohms, 10 watts | TO | VAL-10 |
| R54-1 | Resistor: fixed, composition 180 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R55-1 | Resistor: fixed, composition 47 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R56-1 | Resistor: fixed, composition 560 ohms, 10%, 1/2 watt | O | "Little Devil" |
| R57-1 | Resistor: fixed, composition 68 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R58-1 | Resistor: fixed, composition 100 k ohms, 10%, 2 watts | O | "Little Devil" |
| R59-1 | Resistor: fixed, composition 27 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R60-1 | Resistor: fixed, composition 270 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R61-1 | Resistor: variable, composition 50 k ohms, 2 watts | O | CLU-5031 |
| R62-1 | Resistor: fixed, ww 1 ohm, 5 watts | TO | FRL-5 |

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST, Continued

AMPLIFIER AND POWER SUPPLY

| Component Designation | Description | Mfr.* | Mfr. Part No. |
|---|---|---|---|
| R63-1 | Resistor: variable, composition 250 ohms, 2 watts | O | CLU-5001 |
| R64-1 | Resistor: fixed, composition 1 k ohm, 2 watts | TO | "Little Devil" |
| R65-1<br>R66-1 | Resistor: fixed, composition 47k ohms, 10%, 1/2 watt | O | "Little Devil" |
| RT1-1 | Bulb: incandescent, 6.3 V bayonet base | GE | 1816 |
| S1-1 | Switch: toggle, SPDT | CH | 7590-K6 |
| S2-1 | Switch: toggle, SPST | CH | 7501-K13 |
| T1-1 | Transformer: interstage | T | JO-11 |
| T2-1<br>T3-1 | Transformer: output | T | S24A |
| T4-1 | Transformer: power | OE | 8561 |
| T5-1 | Transformer: power | OE | 8560 |
| V1-1 | Tube: electron, type 12AT7 | GE | 12AT7 |
| V2-1 | Tube: electron, type 12AX7 | GE | 12AX7 |
| V3-1<br>V4-1 | Tube: electron, type 7C5 | SY | 7C5 |
| V5-1 | Tube: electron, type 6C4 | GE | 6C4 |
| V6-1 | Tube: electron, type 12AU7 | GE | 12AU7 |
| V7-1<br>V8-1 | Tube: electron, type 7C5 | GE | 7C5 |
| V9-1 | Tube: electron, type 5U4GT | GE | 5U4GT |
| V10-1 | Tube: electron, type 5AR4 | AX | 5AR4 |
| V11-1 | Tube: electron, type 6BX7 | GE | 6BX7 |
| V12-1 | Tube: electron, type 12AX7 | GE | 12AX7 |
| V13-1 | Tube: electron, type OA2 | SY | OA2 |
| V14-1 | Tube: electron, type 12AX7 | GE | 12AX7 |

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST - continued

RECTANGULAR PATTERN RECORDER HEAD

| Component Designation | Description | Mfr.* | Mfr. Part No. |
|---|---|---|---|
| S4-4<br>S5-4 | Switch: rotary, 5 pole - 3 position | CRL | PA-2015 |
| S6-4 | Switch: toggle, DPDT | CH | 7565-K5 |
| S7-4 | Switch: rotary, 5 pole - 3 position | CRL | PA-2015 |
| S8-4 | Switch: push button, SPST - N. O. | G | 4001 |
| S9-4 | Switch: micro | MS | 1SM1 |
| T1-4 | Transformer: filament 6.3 V AC, 0.6 amperes | T | F-13X |
| | Door, Lower | SA | APR-MB-1010B |
| | Door, Top | SA | APR-MB-1012B |
| | Drum, Pen Cable | SA | APR-MB-1056 |
| | Gear, Pen Drive | SA | APR-MB-1091-A-1 |
| | Holder, Ink Pen | SA | APR-MA-1023A |
| | Pinion, Pen Drive | SA | APR-MB-1091-A-2 |
| | Shaft, Pen Slide | SA | APR-MA-1076A |
| | Window, Top Door | SA | APR-MB-1007A |

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

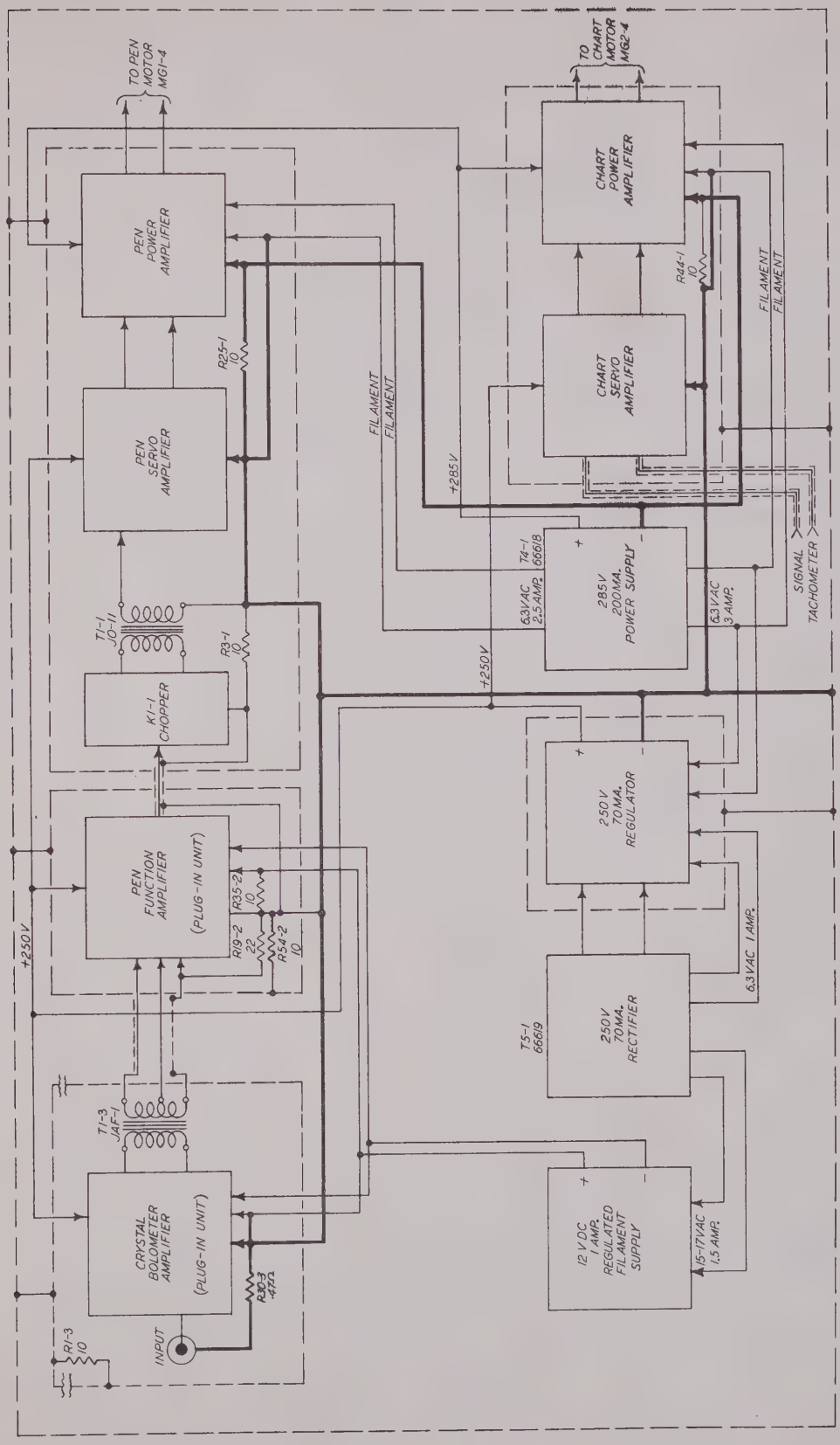



Figure 15. Block Diagram of Recorder Ground Circuit

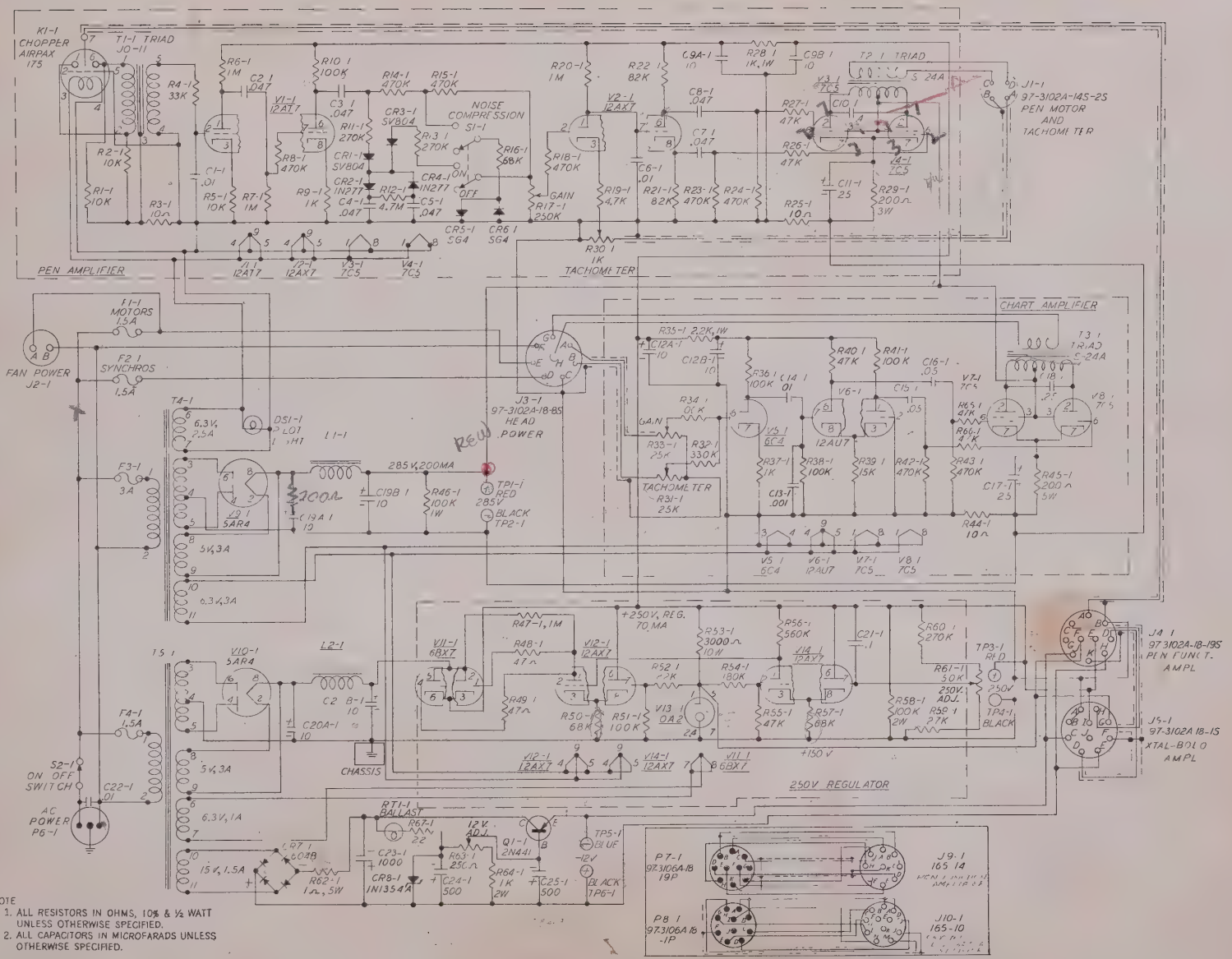
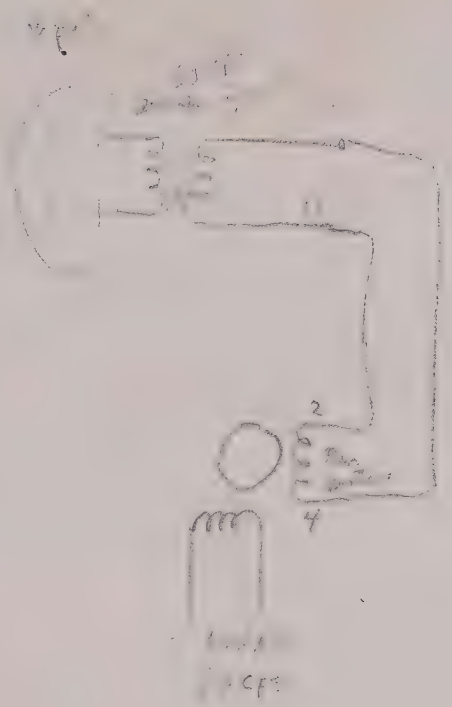



Figure 16. Circuit Diagram of Amplifier and Power Supply Unit.



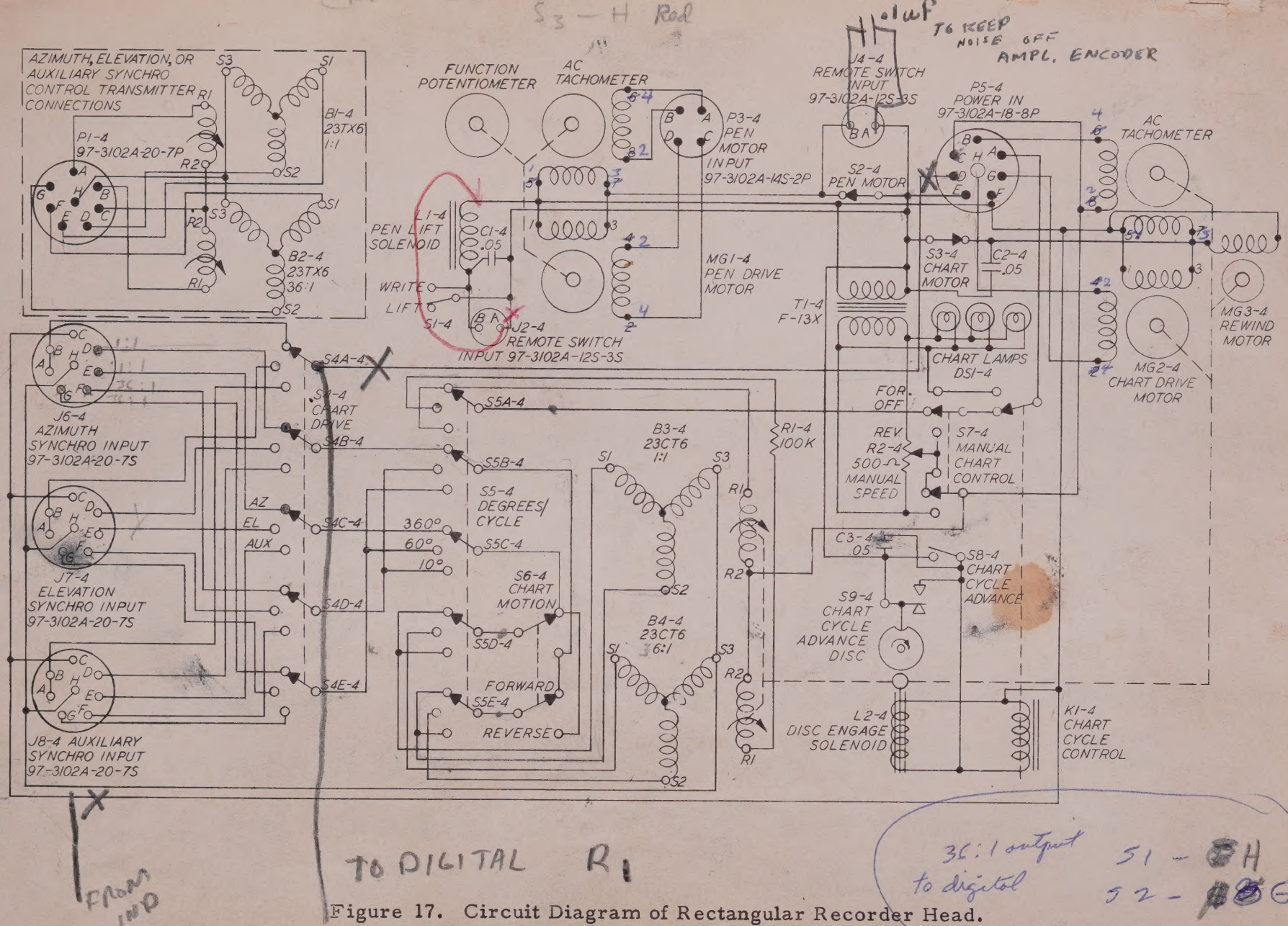



Figure 17. Circuit Diagram of Rectangular Recorder Head.

# CONVERSION OF VOLTAGE AND POWER RATIOS TO DECIBELS

The basic chart below indicates the number of decibels (db) corresponding to the listed ratios of voltage or power over the range of −20 to +20 db. For voltage or power ratios greater than those included in the chart, the ratio can be broken down into a product of two numbers, the value in db for each found separately, and the two results added. Example: To convert a power ratio of 2,000:1 to db, express 2,000 as $2 \times 10^3$; the number of db corresponding to a power ratio of 2 is very nearly 3, and the number of db for a power ratio of $10^3$ is 30. Therefore, the power ratio of 2,000:1 is approximately 30 db + 3 db = 33 db. In the lower right-hand corner of the chart db values for voltage and power ratios of integral powers of 10 are given.

| *Voltage Ratio* | *Power Ratio* | *—db+* | *Voltage Ratio* | *Power Ratio* | *Voltage Ratio* | *Power Ratio* | *—db+* | *Voltage Ratio* | *Power Ratio* | *Voltage Ratio* | *Power Ratio* | *—db+* | *Voltage Ratio* | *Power Ratio* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.000** | **1.000** | **0** | **1.000** | **1.000** | **.447** | **.200** | **7.0** | **2.239** | **5.012** | **.200** | **.0398** | **14.0** | **5.012** | **25.12** |
| .989 | .977 | .1 | 1.012 | 1.023 | .442 | .195 | 7.1 | 2.265 | 5.129 | .197 | .0389 | 14.1 | 5.070 | 25.70 |
| .977 | .955 | .2 | 1.023 | 1.047 | .437 | .191 | 7.2 | 2.291 | 5.248 | .195 | .0380 | 14.2 | 5.129 | 26.30 |
| .966 | .933 | .3 | 1.035 | 1.072 | .432 | .186 | 7.3 | 2.317 | 5.370 | .193 | .0372 | 14.3 | 5.188 | 26.92 |
| .955 | .912 | .4 | 1.047 | 1.096 | .427 | .182 | 7.4 | 2.344 | 5.495 | .191 | .0363 | 14.4 | 5.248 | 27.54 |
| .944 | .891 | .5 | 1.059 | 1.122 | .422 | .178 | 7.5 | 2.371 | 5.623 | .188 | .0355 | 14.5 | 5.309 | 28.18 |
| .933 | .871 | .6 | 1.072 | 1.148 | .417 | .174 | 7.6 | 2.399 | 5.754 | .186 | .0347 | 14.6 | 5.370 | 28.84 |
| .923 | .851 | .7 | 1.084 | 1.175 | .412 | .170 | 7.7 | 2.427 | 5.888 | .184 | .0339 | 14.7 | 5.433 | 29.51 |
| .912 | .832 | .8 | 1.096 | 1.202 | .407 | .166 | 7.8 | 2.455 | 6.026 | .182 | .0331 | 14.8 | 5.495 | 30.20 |
| .902 | .813 | .9 | 1.109 | 1.230 | .403 | .162 | 7.9 | 2.483 | 6.166 | .180 | .0324 | 14.9 | 5.559 | 30.90 |
| **.891** | **.794** | **1.0** | **1.122** | **1.259** | **.398** | **.159** | **8.0** | **2.512** | **6.310** | **.178** | **.0316** | **15.0** | **5.623** | **31.62** |
| .881 | .776 | 1.1 | 1.135 | 1.288 | .394 | .155 | 8.1 | 2.541 | 6.457 | .176 | .0309 | 15.1 | 5.689 | 32.36 |
| .871 | .759 | 1.2 | 1.148 | 1.318 | .389 | .151 | 8.2 | 2.570 | 6.607 | .174 | .0302 | 15.2 | 5.754 | 33.11 |
| .861 | .741 | 1.3 | 1.161 | 1.349 | .385 | .148 | 8.3 | 2.600 | 6.761 | .172 | .0295 | 15.3 | 5.821 | 33.88 |
| .851 | .724 | 1.4 | 1.175 | 1.380 | .380 | .145 | 8.4 | 2.630 | 6.918 | .170 | .0288 | 15.4 | 5.888 | 34.67 |
| .841 | .708 | 1.5 | 1.189 | 1.413 | .376 | .141 | 8.5 | 2.661 | 7.079 | .168 | .0282 | 15.5 | 5.957 | 35.48 |
| .832 | .692 | 1.6 | 1.202 | 1.445 | .372 | .138 | 8.6 | 2.692 | 7.244 | .166 | .0275 | 15.6 | 6.026 | 36.31 |
| .822 | .676 | 1.7 | 1.216 | 1.479 | .367 | .135 | 8.7 | 2.723 | 7.413 | .164 | .0269 | 15.7 | 6.095 | 37.15 |
| .813 | .661 | 1.8 | 1.230 | 1.514 | .363 | .132 | 8.8 | 2.754 | 7.586 | .162 | .0263 | 15.8 | 6.166 | 38.02 |
| .804 | .646 | 1.9 | 1.245 | 1.549 | .359 | .129 | 8.9 | 2.786 | 7.762 | .160 | .0257 | 15.9 | 6.237 | 38.90 |
| **.794** | **.631** | **2.0** | **1.259** | **1.585** | **.355** | **.126** | **9.0** | **2.818** | **7.943** | **.159** | **.0251** | **16.0** | **6.310** | **39.81** |
| .785 | .617 | 2.1 | 1.274 | 1.622 | .351 | .123 | 9.1 | 2.851 | 8.128 | .157 | .0246 | 16.1 | 6.383 | 40.74 |
| .776 | .603 | 2.2 | 1.288 | 1.660 | .347 | .120 | 9.2 | 2.884 | 8.318 | .155 | .0240 | 16.2 | 6.457 | 41.69 |
| .767 | .589 | 2.3 | 1.303 | 1.698 | .343 | .118 | 9.3 | 2.917 | 8.511 | .153 | .0234 | 16.3 | 6.531 | 42.66 |
| .759 | .575 | 2.4 | 1.318 | 1.738 | .339 | .115 | 9.4 | 2.951 | 8.710 | .151 | .0229 | 16.4 | 6.607 | 43.65 |
| .750 | .562 | 2.5 | 1.334 | 1.778 | .335 | .112 | 9.5 | 2.985 | 8.913 | .150 | .0224 | 16.5 | 6.683 | 44.67 |
| .741 | .550 | 2.6 | 1.349 | 1.820 | .331 | .110 | 9.6 | 3.020 | 9.120 | .148 | .0219 | 16.6 | 6.761 | 45.71 |
| .733 | .537 | 2.7 | 1.365 | 1.862 | .327 | .107 | 9.7 | 3.055 | 9.333 | .146 | .0214 | 16.7 | 6.839 | 46.77 |
| .724 | .525 | 2.8 | 1.380 | 1.905 | .324 | .105 | 9.8 | 3.090 | 9.550 | .145 | .0209 | 16.8 | 6.918 | 47.86 |
| .716 | .513 | 2.9 | 1.396 | 1.950 | .320 | .102 | 9.9 | 3.126 | 9.772 | .143 | .0204 | 16.9 | 6.998 | 48.98 |
| **.708** | **.501** | **3.0** | **1.413** | **1.995** | **.316** | **.100** | **10.0** | **3.162** | **10.000** | **.141** | **.0200** | **17.0** | **7.079** | **50.12** |
| .700 | .490 | 3.1 | 1.429 | 2.042 | .313 | .0977 | 10.1 | 3.199 | 10.23 | .140 | .0195 | 17.1 | 7.161 | 51.29 |
| .692 | .479 | 3.2 | 1.445 | 2.089 | .309 | .0955 | 10.2 | 3.236 | 10.47 | .138 | .0191 | 17.2 | 7.244 | 52.48 |
| .684 | .468 | 3.3 | 1.462 | 2.138 | .306 | .0933 | 10.3 | 3.273 | 10.72 | .137 | .0186 | 17.3 | 7.328 | 53.70 |
| .676 | .457 | 3.4 | 1.479 | 2.188 | .302 | .0912 | 10.4 | 3.311 | 10.96 | .135 | .0182 | 17.4 | 7.413 | 54.95 |
| .668 | .447 | 3.5 | 1.496 | 2.239 | .299 | .0891 | 10.5 | 3.350 | 11.22 | .133 | .0178 | 17.5 | 7.499 | 56.23 |
| .661 | .437 | 3.6 | 1.514 | 2.291 | .295 | .0871 | 10.6 | 3.388 | 11.48 | .132 | .0174 | 17.6 | 7.586 | 57.54 |
| .653 | .427 | 3.7 | 1.531 | 2.344 | .292 | .0851 | 10.7 | 3.428 | 11.75 | .130 | .0170 | 17.7 | 7.674 | 58.88 |
| .646 | .417 | 3.8 | 1.549 | 2.399 | .288 | .0832 | 10.8 | 3.467 | 12.02 | .129 | .0166 | 17.8 | 7.762 | 60.26 |
| .638 | .407 | 3.9 | 1.567 | 2.455 | .285 | .0813 | 10.9 | 3.508 | 12.30 | .127 | .0162 | 17.9 | 7.852 | 61.66 |
| **.631** | **.398** | **4.0** | **1.585** | **2.512** | **.282** | **.0794** | **11.0** | **3.548** | **12.59** | **.126** | **.0159** | **18.0** | **7.943** | **63.10** |
| .624 | .389 | 4.1 | 1.603 | 2.570 | .279 | .0776 | 11.1 | 3.589 | 12.88 | .125 | .0155 | 18.1 | 8.035 | 64.57 |
| .617 | .380 | 4.2 | 1.622 | 2.630 | .275 | .0759 | 11.2 | 3.631 | 13.18 | .123 | .0151 | 18.2 | 8.128 | 66.07 |
| .610 | .372 | 4.3 | 1.641 | 2.692 | .272 | .0741 | 11.3 | 3.673 | 13.49 | .122 | .0148 | 18.3 | 8.222 | 67.61 |
| .603 | .363 | 4.4 | 1.660 | 2.754 | .269 | .0724 | 11.4 | 3.715 | 13.80 | .120 | .0145 | 18.4 | 8.318 | 69.18 |
| .596 | .355 | 4.5 | 1.679 | 2.818 | .266 | .0708 | 11.5 | 3.758 | 14.13 | .119 | .0141 | 18.5 | 8.414 | 70.79 |
| .589 | .347 | 4.6 | 1.698 | 2.884 | .263 | .0692 | 11.6 | 3.802 | 14.45 | .118 | .0138 | 18.6 | 8.511 | 72.44 |
| .582 | .339 | 4.7 | 1.718 | 2.951 | .260 | .0676 | 11.7 | 3.846 | 14.79 | .116 | .0135 | 18.7 | 8.610 | 74.13 |
| .575 | .331 | 4.8 | 1.738 | 3.020 | .257 | .0661 | 11.8 | 3.890 | 15.14 | .115 | .0132 | 18.8 | 8.710 | 75.86 |
| .569 | .324 | 4.9 | 1.758 | 3.090 | .254 | .0646 | 11.9 | 3.936 | 15.49 | .114 | .0129 | 18.9 | 8.811 | 77.62 |
| **.562** | **.316** | **5.0** | **1.778** | **3.162** | **.251** | **.0631** | **12.0** | **3.981** | **15.85** | **.112** | **.0126** | **19.0** | **8.913** | **79.43** |
| .556 | .309 | 5.1 | 1.799 | 3.236 | .248 | .0617 | 12.1 | 4.027 | 16.22 | .111 | .0123 | 19.1 | 9.016 | 81.28 |
| .550 | .302 | 5.2 | 1.820 | 3.311 | .246 | .0603 | 12.2 | 4.074 | 16.60 | .110 | .0120 | 19.2 | 9.120 | 83.18 |
| .543 | .295 | 5.3 | 1.841 | 3.388 | .243 | .0589 | 12.3 | 4.121 | 16.98 | .108 | .0118 | 19.3 | 9.226 | 85.11 |
| .537 | .288 | 5.4 | 1.862 | 3.467 | .240 | .0575 | 12.4 | 4.169 | 17.38 | .107 | .0115 | 19.4 | 9.333 | 87.10 |
| .531 | .282 | 5.5 | 1.884 | 3.548 | .237 | .0562 | 12.5 | 4.217 | 17.78 | .106 | .0112 | 19.5 | 9.441 | 89.13 |
| .525 | .275 | 5.6 | 1.905 | 3.631 | .234 | .0550 | 12.6 | 4.266 | 18.20 | .105 | .0110 | 19.6 | 9.550 | 91.20 |
| .519 | .269 | 5.7 | 1.928 | 3.715 | .232 | .0537 | 12.7 | 4.315 | 18.62 | .104 | .0107 | 19.7 | 9.661 | 93.33 |
| .513 | .263 | 5.8 | 1.950 | 3.802 | .229 | .0525 | 12.8 | 4.365 | 19.05 | .102 | .0105 | 19.8 | 9.772 | 95.50 |
| .507 | .257 | 5.9 | 1.972 | 3.890 | .227 | .0513 | 12.9 | 4.416 | 19.50 | .101 | .0102 | 19.9 | 9.886 | 97.72 |
| **.501** | **.251** | **6.0** | **1.995** | **3.981** | **.224** | **.0501** | **13.0** | **4.467** | **19.95** | **.100** | **.0100** | **20.0** | **10.000** | **100.00** |
| .496 | .246 | 6.1 | 2.018 | 4.074 | .221 | .0490 | 13.1 | 4.519 | 20.42 | | | | | |
| .490 | .240 | 6.2 | 2.042 | 4.169 | .219 | .0479 | 13.2 | 4.571 | 20.89 | | $10^{-3}$ | 30 | | $10^{3}$ |
| .484 | .234 | 6.3 | 2.065 | 4.266 | .216 | .0468 | 13.3 | 4.624 | 21.38 | $10^{-2}$ | $10^{-4}$ | 40 | $10^{2}$ | $10^{4}$ |
| .479 | .229 | 6.4 | 2.089 | 4.365 | .214 | .0457 | 13.4 | 4.677 | 21.88 | | | | | |
| | | | | | | | | | | | $10^{-5}$ | 50 | | $10^{5}$ |
| .473 | .224 | 6.5 | 2.113 | 4.467 | .211 | .0447 | 13.5 | 4.732 | 22.39 | $10^{-3}$ | $10^{-6}$ | 60 | $10^{3}$ | $10^{6}$ |
| .468 | .219 | 6.6 | 2.138 | 4.571 | .209 | .0437 | 13.6 | 4.786 | 22.91 | | $10^{-7}$ | 70 | | $10^{7}$ |
| .462 | .214 | 6.7 | 2.163 | 4.677 | .207 | .0427 | 13.7 | 4.842 | 23.44 | $10^{-4}$ | $10^{-8}$ | 80 | $10^{4}$ | $10^{8}$ |
| .457 | .209 | 6.8 | 2.188 | 4.786 | .204 | .0417 | 13.8 | 4.898 | 23.99 | | $10^{-9}$ | 90 | | $10^{9}$ |
| .452 | .204 | 6.9 | 2.213 | 4.898 | .202 | .0407 | 13.9 | 4.955 | 24.55 | | | | | |
| | | | | | | | | | | $10^{-5}$ | $10^{-10}$ | 100 | $10^{5}$ | $10^{10}$ |
| | | | | | | | | | | | $10^{-11}$ | 110 | | $10^{11}$ |
| | | | | | | | | | | $10^{-6}$ | $10^{-12}$ | 120 | $10^{6}$ | $10^{12}$ |


**SCIENTIFIC-ATLANTA, INC.**

2162 PIEDMONT RD., N. E. • ATLANTA 9, GA.

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